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ASSESSMENT OF THE EFFECTIVENESS OF ROZOL®, PHOSTOXIN®, STRYCHNINE, EXIT®, RODENATOR®, AND VARIOUS TREATMENTS, TO CONTROL RICHARD SON'S GROUND SQUIRRELS

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ALPHA WILDLIFE
RESEARCH & MANAGEMENT LTD.

The Richardson's Ground Squirrel (*Spermophilus richardsonii*) Research & Control Program 2009-2010

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SUMMARY

In an effort to develop a sustainable, integrated Richardson's ground squirrel (*Spermophilus richardsonii*) management program in the Canadian Prairies, this research program aimed to 1) assess and compare, in spring and summer, the control efficacy and selectivity of strychnine, chlorophacinone and aluminum phosphide, 2) investigate the ground squirrel-vegetation height relationship, 3) assess and develop capture-efficient trapping devices, and 4) assess predator-prey relationships in southwest Saskatchewan.

The 2009 toxicant study, when combined with the results of 2007 and 2008 research programs led to the following conclusions:

- Phostoxin® is effective when it is applied in fields with vegetation and moist soil.
- Rozol® and Ground Force® are effective in grasslands, but less efficient in alfalfa fields, both in spring and summer.
- Oat baits treated with freshly produced and freshly mixed 0.4% liquid strychnine (Nu-gro) have the potential to effectively control ground squirrel populations.
- Ready-to-use strychnine baits do not have the potential to control at least 70% of ground squirrel populations.

This study showed that the presence of ground squirrels dropped significantly when vegetation reached a minimum height of only 15 cm.

The GT2006 killing trap can be expected to render ≥ 70% of captured Richardson's ground squirrels irreversibly unconscious in ≤ 3 minutes ($P = 0.05$). This trapping device is best suited for the control of ground squirrels in areas where chemical control is not a solution, and for small population concentrations. Multi-capture pen traps with drop-doors mounted on side walls, with strychnine in their centre, were found as effective as strychnine baits placed in burrow openings. No primary poisoning of non-target species and secondary poisoning of predators occurred.

This study showed that badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), and red fox (*Vulpes vulpes*) food habits consisted mainly of ground squirrels in spring and summer, particularly in June-July. Coyotes (*Canis latrans*) did not appear to be as effective as the other terrestrial predators, but they may still have an impact on ground squirrel populations when they have their pups. Badgers did not establish their home range and hunting grounds at random. Their distribution across landscapes suggested that they associate with larger concentrations of Richardson's ground squirrels, and therefore aim to maximize their foraging activities.

On the basis of these findings, it is recommended that strychnine baits be further tested with additives and attractants. Tests should include the multi-capture pen trap design in the assessment of its potential to control ground squirrel populations over large areas. Badger multi-scale habitat selection and red fox hunting activities should be further investigated.

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1.0 INTRODUCTION

In an effort to develop a sustainable, integrated Richardson's ground squirrel (*Spermophilus richardsonii*) management program in the Canadian Prairies, Alpha Wildlife Research & Management Ltd. conducted extensive research on toxicants, predation and grassland characteristics in Saskatchewan, in 2008. Researchers found that, in spring, chlorophacinone (anticoagulant sold as Rozol® and Ground Force®), freshly mixed (FM) 0.4% strychnine-treated oats, and Phostoxin® had the potential to control ≥70% of ground squirrel populations (Proulx et al. 2009a). In summer, however, only FM 0.4% strychnine-treated oats were effective. During both seasons, non-target poisoning was confirmed, particularly in study plots with strychnine-treated baits. Secondary poisoning of predators was confirmed in anticoagulant-treated study plots. Badger (*Taxidea taxus*) and long-tailed weasels (*Mustela frenata*) were significant predators of Richardson's ground squirrels from April to July. Coyote (*Canis latrans*) food habits were more diversified, and Richardson's ground squirrel remains were found in ≥ 50% of scats in April-July (Proulx et al. 2009b). While toxicants and predators impact on Richardson's ground squirrel population densities, Proulx and MacKenzie (2009) found that the density of Richardson's ground squirrel burrow openings decreased significantly when vegetation height was ≥15 cm. The 2008 research findings suggested that Richardson's ground squirrel populations may be controlled with the concurrent use of toxicants, predation and vegetation management. However, in order to account for annual variations in environmental conditions and the efficacy of control methods, Alpha Wildlife researchers suggested that studies be repeated in 2009.

2.0 STUDY AREA

The study was carried out in southern Saskatchewan, near Hazenmore and Ponteix (Figure 1).

Figure 1. Location of the study area.

3.0 TOXICANTS

3.1 Objectives

1. Assess and compare, in spring and summer, the effectiveness (taking into consideration spring and summer natural mortality) of the following products or methods of application to control Richardson's ground squirrels:
   - FM 0.4% strychnine (Nu-Gro Corporation)-treated oats placed in burrow openings in grasslands and alfalfa fields;
   - FM 0.4% strychnine (Nu-Gro Corporation)-treated alfalfa pellets placed in burrow openings in grasslands;
   - FM 0.4% strychnine (Nu-Gro Corporation)-treated oats placed in selective pen traps;
   - FM 0.4% strychnine (Maxim Corporation)-treated oats placed in burrow openings in grasslands;
   - RTU 0.4% strychnine (Nu-Gro Corporation)-treated oats placed in burrow openings in grasslands;
   - Rozol® (Nu-Gro Corporation)-treated oats placed in burrow openings in grasslands and alfalfa fields;
   - Rozol® (Nu-Gro Corporation)-treated oats placed in 17% (1 out of 6 openings) of burrow openings in grasslands;
   - Rozol® (Nu-Gro Corporation)-treated oats @ ½ concentration placed in burrow openings of grassalnds;
   - Rozol® (Nu-Gro Corporation)-treated oats @ ½ concentration placed in 17% (1 out of 6 openings) of burrow openings in grasslands;
   - Ground Force® (Nu-Gro Corporation)-treated winter wheat placed in burrow openings in grasslands and alfalfa fields;
   - Phostoxin® (Degesch America Inc.) pellets placed in burrow openings in grasslands and alfalfa fields.
2. Document the potential impact of these toxicants on non-target species and mammal predators.

3.2 Study Plots

Study plots corresponded to native or seeded grasslands, and pure or mixed alfalfa fields (Table 1) that were located within a same quarter section or in different ones. When located within a same quarter section, study plots were separated by a >150-m-wide buffer zone. In order to capture a similar number of Richardson's ground squirrels from one study plot to the other, the size of the plots varied from 0.2 to 1.4 ha in spring, and 0.2 to 1.1 ha in summer.

Table 1. Characteristics of study plots and Richardson's ground squirrel populations before and after treatment, spring and summer 2009.

Treatment	Study plot	Size (ha)	Habitat	Pre-treatment							Post-treatment							Natural Mortality (%)		Control efficacy (%)
				Adult		Juvenile		Total		Density /ha	Adult		Juvenile		Total		Density/ ha			
				M	F	M	F	Ad.	Ju.		M	F	M	F	Ad.	Ju.		Ad.	Ad & Ju.	
Spring(5 May – 1 June)																				
Rozol® in grasslands	1	1.2	Crested wheat (*Agropyron cristatum*) and needle-and-thread grass (*Hesperostipa comata*)	4	13	-	-	17	-	14.1 ad	0	3	-	-	3	-	2.5 ad	-	-	75.0
	2	0.8		8	12	-	-	20	-	25.0 ad	2	0	-	-	2	-	2.5 ad	-	-	85.8
Ground Force® in grasslands	3	0.7		7	13	-	-	20	-	28.6 ad	0	1	-	-	1	-	1.4 ad	-	-	92.9
	4	0.6		6	14	-	-	20	-	33.3 ad	0	3	-	-	3	-	5.0 ad	-	-	78.8
Rozol® in 17% of burrow openings	5	0.4		10	10	-	-	20	-	50.0 ad	2	1	-	-	3	-	7.5 ad	-	-	78.8
	6	0.4		10	10	-	-	20	-	50.0 ad	2	4	-	-	6	-	15.0 ad	-	-	57.5
Rozol® at half concentration	7	0.5		6	14	-	-	20	-	40.0 ad	1	0	-	-	1	-	2.5 ad	-	-	92.9
	16	0.5		5	15	-	-	20	-	40.0 ad	0	3	-	-	3	-	6.0 ad	-	-	78.8
RTU 0.4% strychnine	9	0.7		3	17	-	-	20	-	28.6 ad	1	4	-	-	5	-	7.1 ad	-	-	64.6
	33/34	3.5	Crested wheat	10	15	-	-	25	-	7.1 ad	1	6	-	-	7	-	2.0 ad	-	-	60.3
Phostoxin® in grasslands (flagged holes)	10/11	1.3	Crested wheat and needle-and-thread grass	11	46	13	19	57	32	43.8 ad	2	3	0	0	5	0	3.8 ad	-	-	87.6 of adults 92.0 of all animals
Rozol® half concentration, in 17% of burrow openings	13	0.8		4	14	-	-	18	-	22.5 ad	1	3	-	-	4	-	5.0 ad	-	-	68.5
	14	0.5		11	10	-	-	21	-	42.0 ad	2	2	-	-	4		8.0 ad	-	-	73.0
FM 0.4% Nu-Gro strychnine in alfalfa-grass mix	17	1.1	70% alfalfa (*Medicago* spp.) with crested wheat and brome (*Bromus* spp.)	10	12	-	-	22	-	20.0 ad	0	3	-	-	3	-	2.7 ad	-	-	80.7
	18	0.8		10	4	-	-	14	-	17.5 ad	2	1	-	-	3	-	3.8 ad	-	-	69.6
Phostoxin® in alfalfa-grass mix (non-flagged holes)	19/20/ 21	5.4		18	14	2	2	32	4	5.9 ad	6	4	0	0	10	0	1.9 ad	-	-	55.7 of adults 60.6 of all animals
Rozol® in pure alfalfa	23	0.6	Alfalfa	6	15	-	-	21	-	35.0 ad	3	3	-	-	6	-	10.0 ad	-	-	59.5
	24	0.8		7	10	-	-	17	-	21.2 ad	1	3	-	-	4	-	5.0 ad	-	-	66.7
Ground Force® in pure alfalfa	25	0.6	Alfalfa	5	9	-	-	14	-	23.3 ad	2	2	-	-	4	-	6.7 ad	-	-	59.5
	26	0.6		8	9	-	-	17	-	28.3 ad	1	2	-	-	3	-	5.0 ad	-	-	75.0
FM 0.4% Nu-Gro strychnine in grassland	27	2.2	Crested wheat	5	15	-	-	20	-	9.1 ad	0	2	-	-	2	-	0.9 ad	-	-	85.8
	28	0.9		11	9	-	-	20	-	22.2 ad	1	3	-	-	4	-	4.4 ad	-	-	71.7
FM 0.4% Nu-Gro strychnine-treated alfalfa pellets in grassland	29	1.8		16	5	-	-	21	-	11.7 ad	5	0	-	-	5	-	2.8 ad	-	-	66.3
	30	0.8		9	12	-	-	21	-	26.3 ad	2	7	-	-	9	-	11.3 ad	-	-	60.7

Table 1 – Cont'd.

Treatment	Study plot	Size (ha)	Habitat	Pre-treatment						Density /ha	Post-treatment						Density/ ha	Natural Mortality (%)		Control efficacy (%)
				Adult		Juvenile		Total			Adult		Juvenile		Total					
				M	F	M	F	Ad.	Ju.		M	F	M	F	Ad.	Ju.		Ad.	Ad & Ju.	
FM 0.4% Maxim strychnine in grassland	31	0.9		12	8	-	-	20	-	22.2 ad	5	1	-	-	6	-	6.7 ad	-	-	57.5
	32	1.2		8	12	-	-	20	-	16.7 ad	2	4	-	-	6	-	5.0 ad	-	-	57.5
Control (no-treatment)	8	0.7	Crested wheat and needle-and-thread grass	4	18	10	9	22	19	31.4 ad	2	9	4	6	11	10	15.8 ad	50.0	51.2	-
	12	0.7	70% alfalfa with crested wheat and brome	14	8	5	3	22	8	31.4 ad	10	8	3	3	18	6	25.7 ad	18.2	20.0	-
	22	0.7	Crested wheat and needle-and-thread grass	7	13	7	5	20	12	28.6 ad	6	10	4	3	16	7	22.9 ad	20.0	28.1	-
Summer (14 June – 2 July)																				
Rozol® in grasslands	19	0.3	Crested wheat	-	-	10	10	-	20	66.7 ju	-	-	1	1	-	2	6.7 ju	-	-	86.1
	22	0.4		-	-	11	9	-	20	50.0 ju	-	-	2	0	-	2	5.0 ju	-	-	86.1
Ground Force® in grasslands	21	0.4		-	-	14	6	-	20	50.0 ju	-	-	0	0	-	0	0.0 ju	-	-	100.0
	24	0.6		-	-	10	11	-	21	35.0 ju	-	-	1	0	-	1	1.7 ju	-	-	93.4
Rozol® in 17% of burrow openings	14	0.3	Dry, rocky, native grassland	-	-	10	11	-	21	70.0 ju	-	-	1	4	-	5	16.7ju	-	-	66.9
	16	0.6		-	-	12	8	-	20	33.3 ju	-	-	2	1	-	3	5.0 ju	-	-	79.1
Rozol® at half concentration	13	0.4		-	-	11	9	-	20	50.0 ju	-	-	4	2	-	6	15.0 ju	-	-	58.3
	15	0.3		-	-	12	8	-	20	66.7 ju	-	-	2	4	-	6	20.0 ju	-	-	58.3
RTU 0.4% strychnine	2	0.3	Crested wheat	-	-	7	14	-	21	70.0 ju	-	-	4	7	-	11	36.7 ju	-	-	27.1
	7	0.4	Open grassland with crested wheat and native grasses	-	-	11	10	-	21	52.5 ju	-	-	2	5	-	7	17.5 ju	-	-	53.6
Phostoxin® in grasslands (flagged holes)	20	1.7	Crested wheat	-	-	14	13	-	27	15.9 ju	-	-	6	2	-	8	4.7 ju	-	-	58.8
Rozol®, half concentration, in 17% of burrow openings	18	0.6	Crested wheat	-	-	4	19	-	23	38.3 ju	-	-	0	7	-	7	11.7 ju	-	-	57.7
	23	0.7		-	-	12	9	-	21	30.0 ju	-	-	3	2	-	5	7.1 ju	-	-	66.9

Table 1 – Cont'd.

Treatment	Study plot	Size (ha)	Habitat	Pre-treatment						Density juveniles/ ha	Post-treatment						Density/ ha	Natural Mortality (%)		Control efficacy (%)
				Adult		Juvenile		Total			Adult		Juvenile		Total					
				M	F	M	F	Ad.	Ju.		M	F	M	F	Ad.	Ju.		Ad.	Ad. & ju.	
0.4% Nu-Gro strychnine in alfalfa-grass mix	5	0.3	60% alfalfa with crested wheat	-	-	8	12	-	20	66.7 ju	-	-	3	3	-	6	20.0 ju	-	-	58.3
	8	0.7		-	-	11	10	-	21	30.0 ju	-	-	3	3	-	6	8.6 ju	-	-	60.2
Phostoxin® in alfalfa-grass mix (flagged holes)	9	0.6		-	-	7	16	-	23	38.3 ju	-	-	0	3	-	3	5.0 ju	-	-	81.9
Rozol® in alfalfa	4	0.3	60% alfalfa with crested wheat	-	-	8	13	-	21	70.0 ju	-	-	0	1	-	1	3.3 ju	-	-	93.4
	11	0.4	90% alfalfa	-	-	10	8	-	18	45.0 ju	-	-	1	4	-	5	12.5 ju	-	-	61.4
Ground Force® in alfalfa	3	0.3	60% alfalfa with crested wheat	-	-	11	10	-	21	52.5 ju	-	-	1	0	-	1	3.3 ju	-	-	93.4
	12	0.3	90% alfalfa	-	-	12	10	-	22	73.3 ju	-	-	7	0	-	7	23.3 ju	-	-	55.7
0.4% Nu-Gro strychnine in grassland	27	0.3	Crested wheat	-	-	13	9	-	22	73.3 ju	-	-	4	2	-	6	20.0 ju	-	-	62.1
	28	0.5		-	-	8	12	-	20	40.0 ju	-	-	2	4	-	6	12.0 ju	-	-	58.3
FM 0.4% Nu-Gro strychnine-treated alfalfa pellets in grassland	1	0.6	Open grassland with crested wheat and native grasses	-	-	13	8	-	21	35.0 ju	-	-	7	2	-	9	15.0 ju	-	-	40.4
	6	0.3		-	-	12	10	-	22	73.3 ju	-	-	5	2	-	7	23.3 ju	-	-	55.7
FM 0.4% Maxim strychnine in grassland	25	0.3	Crested wheat	-	-	9	11	-	20	66.7 ju	-	-	3	3	-	6	20.0 ju	-	-	58.3
	26	0.2		-	-	9	11	-	20	100.0 ju	-	-	2	5	-	7	35.0 ju	-	-	51.3
Control (no-treatment)	10	0.4	60% alfalfa with crested wheat and brome	-	-	12	8	-	20	50.0 ju	-	-	8	6	-	14	35.0 ju	-	30.0	-
	17	0.2	Crested wheat	-	-	9	14	-	23	115.0 ju	-	-	8	9	-	17	85.0 ju	-	26.1	-
FM 0.4% strychnine(Nu-Gro Corporation)-treated oats placed in selective pen traps	29	0.1		-	-	6	6	-	12	120.0 ju	-	-	4 cap	3 cap	-	7 cap	-	-	-	58.3
	30	0.1		-	-	6	8	-	14	140.0 ju	-	-	4 cap	3 cap	-	7 cap	-	-	-*	50.0

M = male, F = female, Ad. = adult, ju = juvenile, cap = captured

*No natural mortality

3.3 Methods

Live-trapping was conducted in spring (5 May-1 June) and summer (14 June-2 July) using 15 x 15 x 48 cm Tomahawk (Tomahawk Live Trap, Tomahawk, Wisconsin) live-traps baited with peanut butter on bread. Traps were set early in the morning and checked by mid-afternoon. All ground squirrels were tagged (Monel # 1 tag, Newport, Kentucky, USA) in both ears. Their sex, weight, and general body condition were recorded before releasing them at their capture site. In spring, captured populations consisted of adult Richardson's ground squirrels in most study plots; in Phostoxin® plots, both adults and juveniles made up the populations. In summer, only juveniles were included in the populations. Live-trapping followed the highest standards of humaneness (Powell and Proulx 2003).

The exact size of study plots was determined on the basis of capture locations. Toxicants were applied at burrow systems where captures and recaptures occurred, and in all the holes with signs of activity located within the delineated study plots. The efficacy of Phostoxin® was tested in fields where burrow holes had been flagged the day before treatment, and in fields where burrow holes were not flagged. Particular attention was paid to the identification of burrow systems that may be inhabited by carnivores, and particularly species at risk such as the swift fox (*Vulpes velox*) and the burrowing owl (*Athene cunicularia*). Burrows with fresh signs of badger (*Taxidea taxus*) and long-tailed weasels (*Mustela frenata*) were not treated with toxicants.

Phostoxin® aluminum phosphide tablets were deposited in Richardson's ground squirrel holes in spring and summer. The application occurred in the morning, before sunrise. All burrow systems were filled with dirt immediately after treatment. In spring, because vegetation was short (< 10 cm) in both the grassland and the alfalfa-grass mix study plots, burrow openings were flagged in the grassland only because of the high density of animals and burrow systems. However, because spring results suggested that not flagging burrow openings may result in lower control efficacy, all study plots were flagged during the summer tests.

Early in the morning, one tablespoon of strychnine bait (approximately 13-15 g; FM and RTU) was placed with a long-handled spoon as far as possible into burrow openings. As per label instructions, the treated holes were covered with dirt. Rozol® was used at standard (i.e., 0.7% chlorophacinone mixed with hulless oats at a weight by weight ratio of 1:13), or half concentration, in all burrow openings or in 17% of openings, as specified in different test protocols. Ground Force® (ready-to-use 0.005% chlorophacinone-treated, green-colored, winter wheat grains; Nu-Gro Corporation, Brantford, Ontario) was deposited in all burrow entrances. All anticoagulant baits were placed in burrow openings early in the morning. A second treatment of burrow openings occurred 48 hours later. No oats were deposited in burrow openings in control study plots[1].

[1] In 2008, non-treated oats had been deposited in burrow openings and covered with dirt in control study plots. In the following days, all holes had been re-opened, and no death was incurred by the treatment. This procedure was not repeated in 2009 to save time and material.

3.4 Assessment of the control efficacy of toxicants

In each study plot, live trapping was initiated the day following the last treatment, and lasted up to 15 days to capture all animals present. An attempt was made to recover carcasses of ground squirrels and non-target species that died on surface. Dead animals were collected and identified to species; a few carcasses were autopsied to confirm the presence of baits in their cheeks and digestive system. All collected carcasses were buried in a 60 cm-deep dirt hole. When moribund animals were found, they were quickly and humanely dispatched with a blow to the head.

The control efficacy of toxicants was evaluated using the Abbott's formula modified by Henderson and Tilton (1955) as follows[2]:

$$M = 100 \times [1 - (t2 \times c1)/(t1 \times c2)]$$

Where M (%) = Richardson's ground squirrel mortality, t = treated population, c = control population, 1 = population before treatment, and 2 = population after treatment.

3.5 Performance criterion

The control efficacy of each toxicant was evaluated in 2 study plots. A toxicant was found acceptable if, in both study plots, it controlled at least 70% of ground squirrel populations (Matschke and Fagerstone 1984, Proulx 2002). The 70% minimum acceptation level was also used when comparing the performance of toxicants over the years.

3.6 Statistical analyses

Because there may be a marked variation in bait rejection from one study plot to the other (Proulx and Walsh 2007, Proulx et al. 2009a), and in order to take into account the possible variation in the behavior of animals from different populations, results from similar treatments were not pooled together for statistical analysis. The Fisher Exact Probability test and Chi-square statistics (Siegel 1956) were used to compare the efficacy of baits among them (Witmer et al. 1995, Proulx 1998, Ramey et al. 2002, Arjo and Nolte 2004). Analysis

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[2] In the past, control efficacy was calculated by subtracting the average natural mortality of populations from that of poison-treated populations (Proulx and Walsh 2007). In this study, in order to be found acceptable, a toxicant had to control ≥ 70% of the ground squirrels of a population. However, if the natural mortality exceeds 30%, a toxicant cannot pass the acceptable criterion unless it kills all animals that survived natural mortality. In order to calculate the true effectiveness of toxicants, control efficacy must be calculated on the number of animals surviving natural mortality. Therefore, one must assume that all the natural mortality has occurred prior treatment with toxicants. The Abbott's formula modified by Henderson and Tilton (1955) does this. This is certainly true for acute poisons and gases. In the case of anticoagulants, however, poisoned animals forage on surface up to 1 week before succumbing to the poison. Predation may occur on the first day of poisoning when the animals' health is not compromised. Later, predators feed on moribund animals, but the health of these animals had already been compromised by the anticoagulant, which is the real reason for the animals' deaths. Even if the supposition that natural mortality occurred before treatment with anticoagulants may not always be true, it is a necessary assumption to compare the impact of diverse toxicants on Richardson's ground squirrel populations.

of variance (ANOVA) and Tukey tests were used to compare mean control levels of toxicants (Zar 1999). A 0.05 level of significance was used for all tests.

3.7 Results

3.7.1 Spring (5 May-1 June)

3.7.1.1 Pre-treatment Population Characteristics

Captured ground squirrel populations ranged from 14 to 25 adults in most study plots in spring (5 May-1 June). Phostoxin® tests were conducted in larger study plots, and populations ranged from 36 to 89 animals (adults and juveniles) (Table 1). Population densities ranged from 5.9 to 50 adults/ha (Table 1).

3.7.1.2 Control Efficacy

Adult natural mortality ranged from 18.2 to 50% in control plots, and averaged 29.4%. The whole population (adult and juvenile) natural mortality ranged from 20 to 51.2%, and averaged 33.1% (Table 1).

In study plots treated with poison baits, between 1 and 10 animals were re-captured after treatment with toxicants, and population densities ranged from 1.4 to 15 adults/ha (Table 1). Control levels ranged from 57.5 to 92.9% (Table 1). The following toxicants controlled ≥ 70% of ground squirrel populations in both study plots where they were applied: Rozol® in grasslands, Ground Force® in grasslands, and Rozol® at half concentration in grasslands. FM 0.4 % Nu-gro strychnine-treated oats in grasslands almost passed in mixed alfalfa-grass study plots with control levels of 80.7% and 69.6% (Table 1).

Phostoxin® controlled more than 70% of ground squirrels in a grassland where all the holes had been flagged before treatment: it controlled 87.6 of the adults, and 92% of the adult-juvenile population (Table 1). In the mixed alfalfa-grass study plot where holes had not been flagged prior to treatment, it controlled only 55.7% of the adults and 60.6% of the whole marked population (Table 1).

There were not significant differences ($P > 0.05$) between control efficacy levels of most toxicants. However, toxicants with control efficacy levels >79% were significantly ($P < 0.05$) more effective than those with control efficacy levels ≤ 66.7%.

3.7.1.3. Richardson's Ground Squirrels Found Dead on Surface

Dead or dying ground squirrels were found on surface of most study plots (Table 2).

3.7.1.4 Non-target and Secondary Poisoning

Non-target poisoning was confirmed in 5 study plots treated with strychnine baits, and in 1 study plot treated with Rozol® (Table 2).

Table 2. Non-target and secondary poisoning in spring and summer toxicant tests.

Treatment	Study plot	Richardson's ground squirrels found dead or dying on surface	Non-target/secondary poisoning
SPRING			
Rozol in grasslands	1	12	
	2	66	
Ground Force in grasslands	3	18	
	4	34	
Rozol in 17% of burrow openings	5	11	
	6	8	
Rozol @ half concentration	7	19	
	16	5	
RTU 0.4% strychnine	9	9	1 western meadowlark (*Sturnella neglecta*)
	33/34	0	
Phostoxin in grasslands (flagged holes)	10/11	58	
Rozol , half concentration, in 17% of burrow openings	13	5	1 deer mouse (*Peromyscus maniculatus*)
	14	1	
FM 0.4% Nu-Gro strychnine in alfalfa mix	17	15	7 deer mouse, 1 northern harrier (*Circus cyaneus*), 1 Vesper sparrow (*Pooecetes gramineus*)
	18	0	1 deer mouse
Phostoxin in alfalfa mix (non-flagged holes)	19/20/21	0	
Rozol in pure alfalfa	23	17	
	24	7	
Ground Force in pure alfalfa	25	1	
	26	14	
FM 0.4% Nu-Gro strychnine in grassland	27	5	
	28	11	1 Vesper sparrow
FM 0.4% Nu-Gro strychnine-treated alfalfa pellets in grassland	29	1	
	30	2	
FM 0.4% Maxim strychnine in grassland	31	2	1 meadowlark
	32	1	
SUMMER			
Rozol in grasslands	19	0	
	22	1	
Ground Force in grasslands	21	3	
	24	1	
Rozol in 17% of burrow openings	14	1	
	16	3	
Rozol @ half concentration	13	3	1 deer mouse
	15	0	
RTU 0.4% strychnine	2	1	4 deer mouse
	7	0	
Phostoxin in grasslands (flagged holes)	20	0	
Rozol , half concentration, in 17% of burrow openings	18	1	
	23	0	
0.4% Nu-Gro strychnine in alfalfa mix	5		
	8	2	
Phostoxin in alfalfa mix (flagged holes)	9	1	
Rozol in alfalfa	4	2	
	11	1	1 long-tailed weasel
Ground Force in alfalfa	3	7	3 long-tailed weasels
	12	0	
0.4% Nu-Gro strychnine in grassland	27	1	2 deer mouse
	28	7	4 deer mouse, 1 horned lark (*Eremophila alpestris*)
FM 0.4% Nu-Gro strychnine-treated alfalfa pellets in grassland	1	0	
	6	0	
FM 0.4% Maxim strychnine in grassland	25	4	1 deer mouse
	26	1	
FM 0.4% strychnine(Nu-Gro Corporation)-treated oats placed in selective pen traps	29	0	
	30	0	

3.7.2 *Summer (14 June - 2 July)*

3.7.2.1 Pre-treatment Population Characteristics

Captured ground squirrel populations ranged from 20 to 27 juveniles in all study plots (Table 1). Population densities ranged from 15.9 to 140 juveniles/ha (Table 1).

3.7.2.2 Control Efficacy

Juvenile natural mortality was 30% and 26.1% in 2 control plots, and averaged 28.1% (Table 1).

In study plots treated with poison baits, between 0 and 11 animals were re-captured after treatment with toxicants, and population densities ranged from 0 to 23.3 juveniles/ha (Table 1). Control levels ranged from 40.4% to 100% (Table 1). The following toxicants controlled ≥ 70% of ground squirrels in both study plots where they were applied: Rozol® and Ground Force® in grasslands (Table 1). Phostoxin® controlled more than 70% of the ground squirrels in mixed alfalfa-grass study plots where vegetation was >30 cm high. However, in a grass study plot with < 10 cm vegetation and very dry soil conditions, it controlled only 58.8% of the animals (Table 1).

There were not significant differences ($P > 0.05$) between control efficacy levels of toxicants that controlled ≤ 66.9% of the populations. Phostoxin® in the mixed alfalfa-grass study plots and anticoagulants had control levels that were significantly higher ($P < 0.05$) than toxicants that did not meet the 70% acceptation level.

3.7.2.3. Richardson's Ground Squirrels Found Dead on Surface

Dead or dying ground squirrels were found on surface of most toxicants (Table 2).

3.7.2.4 Non-target and Secondary Poisoning

Non-target poisoning was confirmed in 4 study plots treated with strychnine baits, and in 3 study plots treated with anticoagulants (Table 2). Secondary poisoning was confirmed only in fields treated with Rozol® in grasslands and Ground Force®. Autopsies of poisoned long-tailed weasels confirmed internal bleeding. Blood was also seeping from foot pads and gums.

3.7.3 *Synthesis of 2007-2009 results*

The ability of toxicants to control Richardson's ground squirrel populations over the years is presented in Table 3.

Table 3. Multi-year performance of toxicants for Richardson's ground squirrels Proulx and Wash 2007, Proulx et al. 2009a, and this study.

Treatment	Season	Years					
		2007		2008		2009	
		Study plot nos.	Control level (%)	Study plot nos.	Control level (%)	Study plot nos.	Control level (%)
Phostoxin®	Spring	5 (high vegetation, moist soil) 7 (low vegetation, dry soil)	71.4 36.0	23 (low vegetation, moist soil) 25 (low vegetation, moist soil)	78.5 85.1	10/11 (low vegetation, moist soil) 19-21 (low vegetation, moist soil, unflagged burrows)	87.6 (adults)/ 92 (adults + juveniles) 55.7 (adults)/ 60.6 (adults + juveniles)
	Summer	-	-	-	-	9 (high vegetation, moist soil) 20 (low vegetation, dry soil)	81.9 58.8
Rozol® in grasslands	Spring	-	-	8 9	100 89.2	1 2	75.0 85.8
	Summer	-	-	5	67.2	19 22	86.1 86.1
Rozol® in grasslands	Spring	-	-	10 11	100 100	-	-
	Summer	-	-	3	75.4	-	-
Rozol® in alfalfa (pure or mixed)	Spring	3 4	49.7 63.0	-	-	23 24	59.5 66.7
	Summer	-	-	25	50.8	4 11	93.4 61.4
Rozol® in alfalfa (pure or mixed)	Spring	-	-	-	-	-	-
	Summer	-	-	26	40.3	-	-

Table 3. Cont'd

Treatment	Season	Years					
		2007		2008		2009	
		Study plots	Control level (%)	Study plots	Control level (%)	Study plots	Control level (%)
Rozol® in 17% of burrow openings	Spring	-	-	-	-	5 6	78.8 57.5
	Summer	-	-	-	-	14 16	66.9 79.1
Rozol® at half concentration	Spring	-	-	-	-	7 16	92.9 78.8
	Summer	-	-	-	-	13 15	58.3 58.3
Rozol®, half concentration, in 17% of burrow openings	Spring	-	-	-	-	13 14	68.5 73.0
	Summer	-	-	-	-	18 23	57.7 66.9
Rozol® in burrow openings and in perimeter bait stations	Spring	-	-	5 6	100 100	-	-
	Summer	-	-	11 15	50.8 50.8	-	-
Rozol® in bait stations	Spring	-	-	19 20	73.1 85.7	-	-
	Summer	-	-	13 19	62.7 76.6	-	-
Ground Force® in grasslands	Spring	-	-	7 21	95.1 71.9	3 4	92.9 78.8
	Summer	-	-	9	67.2	21 24	100 93.4
Ground Force® in alfalfa (pure or mixed)	Spring	-	-	-	-	25 26	59.5 75.0
	Summer	-	-	10	67.2	3 12	93.4 55.7
FM 0.4% Nu-Gro strychnine with oats in grassland	Spring	6 8	38.1 38.1	3 4	73.1 95.4	27 28	85.8 71.7
	Summer	-	-	4 6	75.4 75.4	27 28	62.1 58.3

Table 3. Cont'd.

Treatment	Season	Years					
		2007		2008		2009	
		Study plots	Control level (%)	Study plots	Control level (%)	Study plots	Control level (%)
FM 0.4% Nu-Gro strychnine with oats in alfalfa mix	Spring	-	-	-	-	17 18	80.7 69.6
	Summer	-	-	-	-	5 8	58.3 60.2
FM 0.4% Nu-Gro strychnine with canary seeds in grassland	Spring	-	-	14 16	84.5 63.9	-	-
	Summer	-	-	1 2	83.4 92.2	-	-
FM 0.4% Nu-Gro strychnine-treated alfalfa pellets in grassland	Spring	-	-	-	-	29 30	66.3 60.7
	Summer	-	-	-	-	1 6	40.4 55.7
FM 0.2% Nu-Gro strychnine with oats in grassland	Spring	-	-	13 15	52.3 48.4	-	-
	Summer	-	-	12 16	59.0 65.8	-	-
FM 0.4% Maxim strychnine in grassland	Spring	-	-	-	-	31 32	57.5 57.5
	Summer	-	-	-	-	25 26	58.3 51.3
RTU 0.4% strychnine in grasslands	Spring	9 10	33.3 59.7	12 18	53.6 47.6	9 33/34	64.6 60.3
	Summer	-	-	7 8	26.2 18.0	2 7	27.1 53.6

Phostoxin® was found effective throughout the years when it was applied in fields with vegetation and moist soil (Table 3). Under dry soil conditions, however, its control efficacy dropped below 70%. Rozol® (including Rozol®+ which has the same concentration of chlorophacinone as the original product but is different due to the addition of a non-lethal attractant) and Ground Force® were effective in grasslands, but failed consistently in alfalfa fields, both in spring and summer. In 2009, they controlled >70% of ground squirrels in one alfalfa field when plants suffered from an extended drought period and were dying. The use of bait stations with Rozol® was tested in 2008 only, and results indicated that, in spring, this method was as effective as depositing poison baits in burrow openings. The efficacy of FM Nu-gro strychnine varied significantly from 2007 (a 2002 formula), to 2008 (produced the same year), and to 2009 (1-year-old solution). Maxim strychnine baits were ineffective in spring and summer 2009. During 3 consecutive years, RTU strychnine failed to control at least 70% of ground squirrel populations. On the basis of 3 years of research, the following datasets may be compared to each other (Table 4):

- Phostoxin® in fields with vegetation and moist soils where the burrow openings have been flagged prior to treatment, spring and summer.
- Rozol® and Rozol®+ in grasslands, spring and summer.
- Rozol® and Rozol®+ in alfalfa (pure or mixed), spring and summer.
- Ground Force® in grasslands, spring and summer.
- Ground Force® in alfalfa (pure and mixed), spring and summer.
- FM Nu-gro 0.4% strychnine, spring and summer 2008.
- FM Nu-gro 0.4% strychnine, spring and summer 2009[3].
- FM 0.4% Maxim strychnine, spring and summer 2009.
- RTU 0.4% strychnine, spring 2007, spring and summer 2008 and 2009.

There was a significant difference ($F_{8,52} = 8.612$, $P < 0.001$) between average control levels of different toxicants. Rozol® and Ground Force® in grasslands, Phostoxin®, FM Nu-gro 0.4% strychnine 2008, and Ground Force® in alfalfa had control levels that were significantly higher ($P < 0.05$) than those of other toxicants (Figure 2). The average control level of FM Nu-gro 0.4% strychnine 2009 was borderline; it was not different ($P > 0.05$) from the average control levels of these high performing toxicants, but it was also similar ($P > 0.05$) to that of toxicants with less performance (Figure 2). RTU 0.4% strychnine had a control level similar ($P > 0.05$) to that of Rozol® in alfalfa and FM 0.4% Maxim strychnine, but lower than that of all other poisons (Table 4, Figure 2). While yearly data suggested that anticoagulants do not perform well in alfalfa fields, 2 years of research showed that, on average, Ground Force® met the 70% acceptation criterion.

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[3] The 2007 data were not considered due to the old age of the strychnine solution.

Table 4. Average control level (%) obtained with different toxicants from 2007 to 2009.

Toxicant (*n*)	Average control level (%)	Standard deviation (%)
Phostoxin® (5)	80.9	6.3
Rozol® in grasslands (10)	86.5	11.5
Rozol® in alfalfa (8)	60.6	15.8
Ground Force® in grasslands (7)	85.6	12.8
Ground Force® in alfalfa (5)	70.2	15.0
FM Nu-gro strychnine 2008 (4)	79.8	10.4
FM Nu-gro strychnine 2009 (8)	68.3	10.5
FM Maxim strychnine (4)	56.2	3.3
RTU strychnine (10)	44.4	16.8

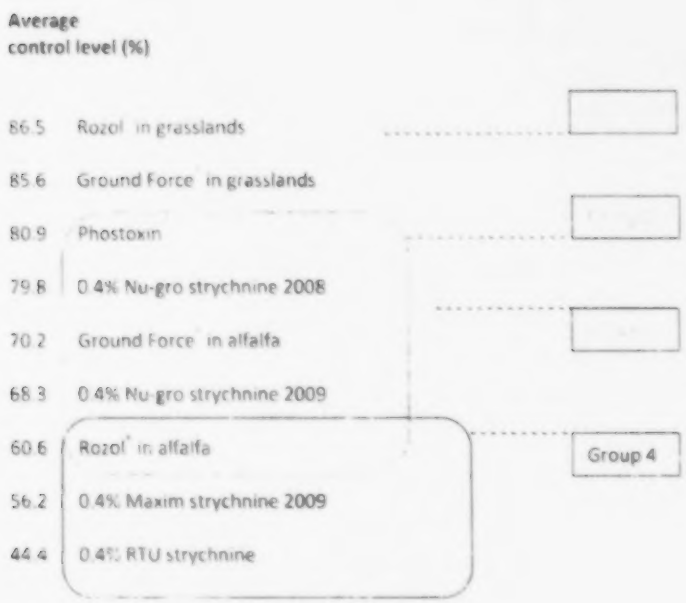

Figure 2. Comparison of the efficacy of various toxicants to control Richardson's ground squirrels. Treatments within a same group had similar ($P > 0.05$) mean control levels.

4.0 GROUND SQUIRREL -VEGETATION HEIGHT RELATIONSHIP

4.1 Objective

- Determine the relationship existing between Richardson's ground squirrel distribution and vegetation height.

4.2 Study Plots

Study plots corresponded to native grasslands used as pastures on short rotational basis (Aneroid), or crested wheat-dominated fields that had not been grazed for at least 2 years (Ponteix, Hazenmore, and Cadillac). In all regions except Cadillac, study plots with vegetation of different heights were adjacent to each other, within a same quarter section. In Cadillac, plots were not adjacent to each other due to the interspersion of tilled fields and annual crops, but they were < 2 km apart.

4.3 Methods

Field investigations of Richardson's ground squirrel abundance in fields with different vegetation heights were carried out from 5 to 20 May. Vegetation was classified according to 3 heights: 1) Low, < 10-cm high; 2) Medium, 15-20-cm high; and 3) Tall, ≥ 30-cm high. Three 0.49 ha study plots, located >10 m from the border of fields and ≥ 10-m-equidistant from each other, were located in each study plot. Ground squirrel burrow openings were inventoried in each study plot by 5 people walking up and down fields, 5-m abreast. Because ground squirrel infestation levels vary among regions, the comparison of burrow opening abundance between fields of different vegetation heights was done at the regional level. However, because there was a marked trend in the abundance of burrow openings according to vegetation heights, data analyses were also carried out on pooled data. Analysis of variance (ANOVA), Tukey tests, and Student-*t* tests, were used to compare mean numbers of burrow openings/quadrat (Zar 1999).

4.3 Results

4.3.1 Ponteix

Three fields with different vegetation heights were found adjacent to each other. There was a significant difference ($F_{2,6} = 12.8$, $P < 0.01$) in the number of Richardson's ground squirrel burrow openings/quadrat (Table 5). The average number of burrow openings/quadrat was significantly higher ($P < 0.05$) in short vegetation than in medium and high vegetation. There was no significant difference ($P > 0.05$) in the mean number of burrow openings/quadrat in medium and high vegetation types.

Table 5. Number of Richardson's ground squirrel burrow openings/0.49 quadrat in fields with short (< 10-cm high), medium (15-20-cm high), and high (> 30-cm high) vegetation, May 2009.

Region	Mean number of burrow openings/0.49 ha quadrat (standard deviation) *		
	Short vegetation	Medium vegetation	Tall vegetation
Ponteix	395.0 (109.1)	173.0 (61.7)	109.0 (12.1)
Aneroid	197.7 (72)	53.7 (24.9)	-
Hazenmore	252.0 (28.6)	-	169.7 (38.2)
Cadillac	124.7 (78)	2.0 (2)	2.3 (4)
Pooled data			
n	12	9	9
Mean	242.3	76.2	93.7
Standard deviation	122.7	82.9	76.1

* *n* = 3 quadrats/vegetation type/region.

4.3.2 Aneroid

Two fields with short and medium vegetation heights were found adjacent to each other. There was a significant difference ($t = 3.318$, $P < 0.05$) in the number of Richardson's ground squirrel burrow openings/quadrat (Table 5). The average number of burrow openings/quadrat was significantly higher in short than in medium vegetation.

4.3.3 Hazenmore

Two fields with short and tall vegetation heights were found adjacent to each other. There was a significant difference ($t = 2.991$, $P < 0.05$) in the number of Richardson's ground squirrel burrow openings/quadrat (Table 5). The average number of burrow openings/quadrat was significantly higher in short than in tall vegetation.

4.3.4 Cadillac

Three fields with different vegetation heights were found nearby each other. There was a significant difference ($F_{2,6} = 7.378$, $P < 0.05$) in the number of Richardson's ground squirrel burrow openings/quadrat (Table 5). The average number of burrow openings/quadrat was significantly higher ($P < 0.05$) in short vegetation than in medium and high vegetation. There was no significant difference ($P > 0.05$) between medium and high vegetation types.

4.3.5 Pooled data

There was a significant difference ($F_{2,27} = 9.237$, $P < 0.005$) in the number of Richardson's ground squirrel burrow openings/quadrat in different vegetation heights (Table 5). The average number of burrow openings/quadrat was significantly higher ($P < 0.05$) in short vegetation than in medium and high vegetation. There was no significant difference ($P > 0.05$) between medium and high vegetation types.

5.0 ASSESSMENT & DEVELOPMENT OF CAPTURE-EFFICIENT TRAPPING DEVICES

5.1 Objective

- Assess and compare the capture efficiency of various live and kill trapping devices.

5.2 Study Plots

All traps were tested in grasslands in Hazenmore and Ponteix.

5.3 Methods

Two trap models were tested and/or developed:

1. GT2006 (Lee's Trapworks Ltd., Swift Current, Saskatchewan): guillotine-type killing trap set individually at burrow openings (Figure 3). When a ground squirrel leaves its burrow system, it must walk through an opening and push on a fork trigger that releases a metal plate that strikes the animal dorsally.

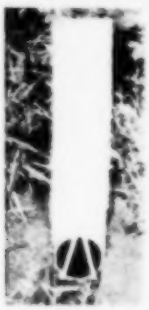

Figure 3. The GT2006 trap.

2. Multi-capture pen trap (Alpha Wildlife, Sherwood Park, Alberta): 90 cm x 90 cm wire-mesh box trap with at least 2 one-way door entrances. (Figure 4).

Figure 4. The pen trap.

Four types of doors (Figure 5) were tested:

- Drop-door in a PVC pipe: the animal pushes the door open, and the door closes back on its own once the animal has cleared the entrance.
- Treadle door in a PVC pipe: the treadle is heavier on one side and, once the animal has walked over it to enter the trap, it falls back in place and blocks the entrance from the inside of the trap.
- Drop-door with locking treadle: the animal pushes the door open (which falls back on its own) to enter the trap. If the animal comes back towards the door, a treadle that is heavier on one side pops up and locks the drop-door in place.
- Drop-door mounted on the side of the pen trap.

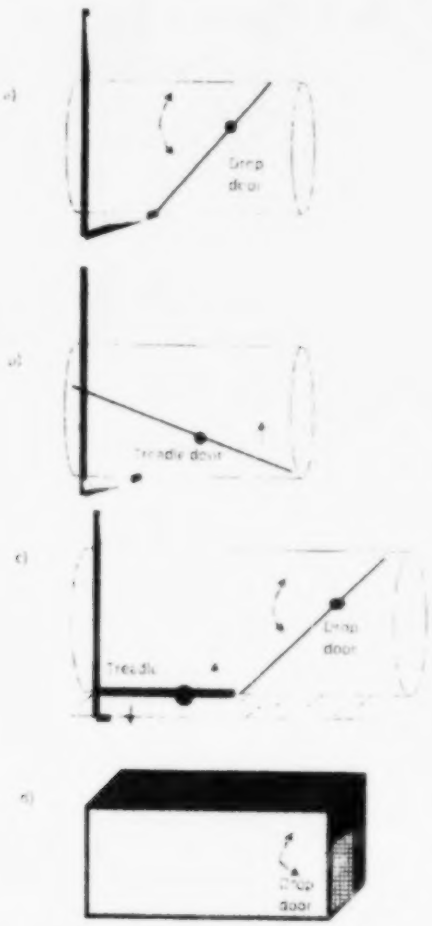

Figure 5. Door models (not at scale) tested with the multi-capture pen trap: a) drop-door in PVC pipe; b) treadle door in PVC pipe; c) drop-door and treadle lock in PVC pipe; and d) drop-door on the side of the pen trap.

The GT2006 trap was tested for its humaneness from 28 June to 6 July. Six taps were repeatedly used for the capture of 9 animals (3 of them were re-used for the capture of a second animal, for a total of 9 captures). One trap was set immediately after a ground squirrel sought refuge in its burrow system. Five more traps were set in neighboring burrow holes that may be connected to the original burrow system. Upon firing of the trap, the researcher started a chronometer, and determined time to loss of consciousness by monitoring the corneal and palpebral reflexes (Proulx et al. 1989). The GT2006 trap was considered humane if it rendered 9 out of 9 ground squirrels irreversibly unconscious in ≤ 3 min. In the event of an animal not losing consciousness within this time period, it would be euthanized with a sharp blow to the head. On the basis of a one-tailed binomial test (Zar 1999), the GT2006 trap would be expected, at a 95% level of confidence, to humanely kill ≥ 70% of all Richardson's ground squirrels captured on traplines (Proulx et al. 1993). This humane standard, developed by Proulx and Barrett (1989), is the best-defined, objective and published criterion consistent with state-of-the art technological development (Powell and Proulx 2003). Time to loss of heartbeat was determined with a stethoscope. Injuries caused by the trap were determined in the field through examination of the carcass. The assessment of the capture efficiency of the GT2006 was limited to observations made during the testing of the humaneness of the trap.

The pen trap was tested for its capture-efficiency. A preliminary assessment of door types consisted in field observations only. Once a door model was judged effective, 2 prototypes of the pen trap were used to assess their efficacy to control Richardson's ground squirrels with strychnine baits. In two 0.1-ha study plots, ground squirrels were captured in Tomahawk traps and tagged as per Section 3.3. A container with FM 0.4% strychnine-treated oats was placed at the centre of each pen trap. Peanut butter was used as attractant. The traps were set from 29 June to 5 July. The number and identity of captured animals were recorded daily. The Fisher Exact Probability test (Siegel 1956) was used to compare the efficacy of pen taps with strychnine to treatments with FM 0.4% Nu-gro strychnine baits, FM 0.4% Maxim strychnine baits, and RTU 0.4% strychnine baits. A 0.05 level of significance was used for all tests.

5.4 Results

5.4.1 GT2006

Nine of 9 juveniles (3 males, 4 females, 2 unknown; 300-470 g) were successfully killed (Table 6). The average time to loss of consciousness and heartbeat were < 40.1 (standard deviation: 49.2) seconds and 125 (± 55.2) seconds, respectively (Table 6). In 7 cases, the animals were struck on the head, and the skull was fractured. In 2 cases, the strike occurred at the skull-neck junction, and the animals died of asphyxiation. This study showed that the GT2006 trap can be expected to render ≥ 70% of captured Richardson's ground squirrels irreversibly unconscious in ≤ 3 minutes ($P = 0.05$).

Table 6. Location of strike, time intervals between trap firing and irreversible loss of corneal and palpebral reflexes and heartbeat of 9 juvenile Richardson's ground squirrels in kill tests with the GT2006 trap, Hazenmore, summer 2009.

Location of strike			*Time of loss after trap firing (sec)*	
Behind or across the ears	***Across the eyes***	***Junction of skull and neck***	***Eye reflexes***	***Heartbeat***
6	1	2	≤10* - 132	48-232

*Animal was unconscious on arrival of researcher.

Time to capture ranged from 5 to 30 minutes, and the targeted animal was not always captured in the burrow opening where it had sought refuge. In 4 out of 9 tests, only 1 animal was captured. In 2 other tests, 2 and 3 animals were captured at the same time in different traps.

5.4.2 Multi-capture (pen) tap

5.4.2.1 Drop-door in PVC pipe

One pen trap set for 2 days in early April captured 7 Richardson's ground squirrels. However, no captures occurred when the trap was set for 2 days in early May. Field observations showed that the animals entered the trap but were able to reopen the drop-door and escape.

5.4.2.2 Treadle door in PVC pipe

One day of testing in mid-May resulted in the capture of 1 adult and 1 juvenile. However, gophers were able to bring down the treadle from inside the trap, and escape.

5.4.2.3 Drop-door with locking treadle

On May 21, only 1 ground squirrel was captured during a 10-h test. Ground squirrels investigated the door but hesitated to enter.

5.4.2.4 Drop-door mounted on the side of the pen trap

A first test conducted on 28 June resulted in the capture of 6 ground squirrels in 10 minutes. In a second test on 30 June, 4 ground squirrels were captured in 3 hours. Animals showed no reluctance in entering the trap, and did not escape. This type of door was therefore adopted for tests with strychnine baits.

5.4.2.4 Pen trap-strychnine tests

A total of 12 and 14 juvenile ground squirrels were captured and ear-tagged in study plots nos. 29 and 30 (Table 1). Because these animals were all captured within 2 days, natural mortality was considered to be nil. Over a 7-day period, pen traps with strychnine baits controlled 58.3% and 50% of the original marked populations (Table 1). Control levels achieved with pen traps was not significantly different ($P > 0.05$) from those obtained with 0.4% Nu-gro strychnine baits, 0.4% Maxim strychnine baits, and RTU 0.4% strychnine baits. There was no poisoning of non-target animals.

6.0 PREDATION

6.1 Objectives

1. Badger:
   - Gather data on the badger population inhabiting the pasture-annual crop complex, including the female mentioned above and her young;
   - Investigate movements and hunting activities of a female badger (no. 207) captured in 2008 and those of neighbouring adults in a pasture-annual crop complex;
   - Estimate the impact of this badger population on the local ground squirrel population; and
   - Gather data on food habits of badgers across landscapes to assess its role as a predator of Richardson's ground squirrels.
2. Long-tailed Weasel:
   - Investigate movements and hunting activities of long-tailed weasels inhabiting the female badger's pasture-annual crop complex mentioned above; and
   - Gather data on food habits of long-tailed weasels across landscapes to assess its role as a predator of Richardson's ground squirrels.
3. Coyote:
   - Gather data on food habits of coyotes across landscapes to assess its role as a predator of Richardson's ground squirrels.
4. Red Fox (*Vulpes vulpes*)[4]
   - Gather data on food habits of red foxes across landscapes to assess its role as a predator of Richardson's ground squirrels.

6.2 Study plots

Data were collected at or nearby study plots used in toxicant (Section 3.0) and vegetation (Section 4.0) studies. Data on the female badger no. 207 were collected north of Hazenmore.

6.3 Methods

6.3.1 Badger

Estimates of badger densities were carried out in study plots used for the assessment of toxicants (Section 3.0) and grounds surrounding the home range of female no. 207. The distribution of animals was determined through animal search where signs of activity had been noted, and encounters when traveling through fields with study plots.

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[4] This species was not part of the original 2009 research proposal. Alpha Wildlife initiated the collection of scats in 2008, and continued in 2009 in order to provide SARM with a better understanding of the effect of terrestrial predators on Richardson's ground squirrels.

Because female no. 207 used the same burrow during all summer, information on its movements was limited. Habitat selection and distribution of activities (as indicated by burrow systems) were investigated at stand and landscape level. The number of Richardson's ground squirrel and badger holes present in the 3 m x 400 m grassland strip encompassing female no. 207 den was compared to that of two 3 m x 400 m control strips, located 15 m east and west of the den. In a study of habitat selection by an unknown badger, the number of Richardson's ground squirrel and badger holes in 2 hunting grounds was compared to that of 2 controls located 30 m away, on each side of the hunting grounds. The size of hunting grounds and control quadrats was standardized at 70 x 70 m.

Knowing female no. 207's home range in fall 2009 (Proulx et al 2009b) and summer 2010 (this study), a landscape section including annual crops and contiguous pasture land was identified. Five 350-m equidistant transects, ranging from 920 to 1265 m in length, were laid out (using 70-m-long rope sections) across crops and pastures in an east-west direction. All Richardson's ground squirrel burrow holes located within 30 cm of either side of the rope were tallied. The same procedure was repeated with an unknown adult badger located 4 km east of female no. 207. Four 200-m-equidistant and 1618-m-long transects were laid across the landscape where the badger had been observed. Transects crossed fallow, alfalfa, wheat, and pasture fields. The length of the transects and their equidistance varied from one study site to another due to the presence of human dwellings, the location of the fields and their accessibility. The proportion of inventory transects within each field type was used to determine the expected frequency of ground squirrel burrow holes per field type. Chi-square statistics with Yates correction (Zar 1999) were used to compare observed to expected frequencies of burrow hole intersects per field type (Proulx & O'Doherty 2006). If the chi-square analysis suggested an overall significant difference between the distributions of observed and expected frequencies, a G test for correlated proportions (Sokal & Rohlf 1981) was used to compare observed to expected frequencies for each field type (Proulx 2006, 2009). Analyses of variances (ANOVA) and Tukey tests were used to compare the average numbers of Richardson's ground squirrel holes in different field types fields of different types (Zar 1999).

The impact of badgers on ground squirrel populations was estimated solely[5] on the basis of scats collected in 2008[6] and 2009. Scats were collected at burrows within and between toxicant study plots. Scat were dated, bagged, and kept frozen until processing. Scat analyses were conducted at Alpha Wildlife Research & Management laboratory in Sherwood Park, Alberta. They were soaked overnight in mild water-bleach solution, washed through a sieve, and oven-dried at 75°C. Scats were analyzed according to Chandler (1916), Adorjan and Kolenosky (1969) and Moore et al. (1974). Comparisons of the frequencies (chi-square

[5] Although we intended to capture badgers and implant transmitters to better understand their movements and assess the effect of their hunting activities on Richardson's ground squirrel populations, we were unable to find badgers in safe locations, i.e., in fields where they would not be endangered by poison bait stations that producers disperse across fields to control ground squirrels. Most of the badgers present in spring had disappeared by early summer.

[6] Due to time constraints, Proulx et al. (2009b) were not able to analyse all scats collected in 2008.

and Fisher tests; Siegel 1956) and mean volume per scat (Student's *t*-test, Mann-Whitney *U* test, analysis of variance followed by the Tukey test; Siegel 1956, Zar 1999) of remains between different periods of the year were made (Proulx et al. 1987). Species richness in each habitat type was determined with the Shannon-Wiener function:

$$H : -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where *s* is the number of species, and *pi* is the proportion of total sample belonging to *i*th species (Krebs 1978).

A simple linear regression model was used to determine the relationship between some variables. Probability values ≤ 0.05 were considered statistically significant.

6.3.2 Long-tailed weasel, coyote and red fox

We were unable to investigate long-tailed weasel movements and hunting activities in no. 207 female badger's pasture-annual crop complex due to the loss of animals to Rozol® poisoning[7].

Scats of long-tailed weasel, coyote, and red fox that were collected in 2008[6] and 2009 were processed as per Section 6.3.1.

6.4 Results

6.4.1 Badger

6.4.1.1 Density of adult badgers in study plots

Observations on the distribution of badgers in study plots suggest a density of approximately 1 adult badger/quarter section (64 ha) in spring and summer (Table 7).

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[7] Our investigation of long-tailed weasels' movements and hunting activities in no. 207 female badger's pasture-annual crop complex was attempted in early July with the capture and radio-collaring of 2 weasels. Even though the pasture-annual crop complex was poison free, one male weasel died within 24 h of being collared. It was likely poisoned by Rozol®. A neighbor had placed bait stations along the edges of the pasture-annual crop complex. A collared female disappeared during the same time period. In 2 study plots (nos. 3 and 11, Table 1) where the efficacy of Rozol® baits was tested, we captured 4 weasels. They all died within 48 h of being captured, <7 days after treating the study plot with Rozol® baits. All animals showed signs of internal bleeding.

Table 7. Density of adult badgers in study plots, spring and summer 2009, southern Saskatchewan.

Time of Year	*Number of badgers*	*Size of the area*	*Vegetation*	*Location*
Spring	1	1 quarter Section	Pure alfalfa and 70% alfalfa with crested wheat and brome	L. Thibault
Summer	3	3 quarter sections	Native grassland with crested wheat grass, sage, blueberry, rose (*Rosa* spp.).	O. Ballas
	3	1 section	Native grassland dominated by crested wheat grass and buckbrush, and annual crops.	N. Mackenzie G. Gross

6.4.1.2 Den site of female no. 207

The den was located within a 3-m-wide grassland strip that crossed a wheat field. Badger activities at the den could not be confirmed due to the animal's shyness (it would seek refuge as soon as it heard a vehicle or saw human activity) and the height of the surrounding crop. There were 54 ground squirrel and 4 badger holes in a 3 m-wide x 400-m-long grassland strip encompassing the den. In one 3 m x 400 m control strip, only 10 ground squirrel holes were recorded. In the other control strip, 6 ground squirrel and 1 badger holes were found. Richardson's ground squirrel and badger activity appeared to be greater in the grassland than in the wheat field.

6.4.1.3 Habitat selection at landscape level

Female no. 207

Three types of vegetation cover were found within the landscape inhabited by female no. 207: grass and buckbrush were present in a coulee that was surrounded by wheat. A total of 158 Richardson's ground squirrel holes were recorded along 5 survey transects (Table 8). The observed distribution of ground squirrel holes per vegetation type differed ($\chi^2 = 50.2$, df: 2, $P < 0.001$) from expected. Ground squirrel holes were significantly less frequent than expected in wheat (G = 4.7, df: 1, $P < 0.05$), but significantly more frequent in grass (G= 6.3, df:1, $P < 0.02$) and buckbrush (G= 6.64, df: 1, $P < 0.02$). Female no. 207 made a greater use of the coulee than the wheat fields, as it was found by Proulx et al. (2009b) in a study of the distribution of hunting grounds. In the coulee, however, the observed distribution of Richardson's ground squirrel holes in grass and buckbrush was not significantly different ($\chi^2 = 50.2$, df : 1, $P > 0.05$) from expected. Because hunting grounds were found in grass only (Proulx et al. 2009b), badger no. 207 appeared to select grass over buckbrush when hunting.

Unknown adult

Four types of cover were found within the landscape inhabited by an unknown adult badger: fallow, alfalfa, wheat, and pasture. A total of 288 Richardson's ground squirrel holes were recorded along 4 survey transects (Table 8). The observed distribution of ground squirrel holes per vegetation type differed ($\chi^2 = 77.1$, df: 3, $P < 0.0001$) from expected. Ground squirrel holes were significantly less frequent than expected in wheat (G = 14.2, df: 1, $P < 0.005$), but significantly more frequent in fallow (G= 9.87, df:1, $P < 0.01$) and alfalfa (G= 9.23, df: 1, $P < 0.01$).

Two hunting grounds were found at the junction of the fallow-alfalfa fields, and in the alfalfa. The number of Richardson ground squirrel and badger holes was markedly higher in hunting grounds than in controls (Table 9). A significant relationship existed between the density of badger holes/ha and the density of Richardson's ground squirrel holes/ha. The linear regression between densities was $Y = 27.4\,X + 31$ ($r = 0.93$, $P < 0.05$) (Figure 6).

Table 8. Distribution of Richardson's ground squirrel burrow holes across landscapes inhabited by badgers, summer 2009.

Vegetation type	*Length (m)/%*	*Number of Richardson's ground squirrel burrow holes/%*
Female no. 207		
Wheat	5035 / 84.6	101 / 63.9
Grass	547 / 9.2	32 / 20.2
Buckbrush	370 / 6.2	25 / 15.8
Total	5952 / 100	158 / 100
Unknown adult		
Fallow	768 / 11.9	65 / 22.6
Alfalfa	360 / 5.6	38 / 13.2
Wheat	2128 / 32.9	50 / 17.4
Pasture	3216 / 49.7	135 / 46.9
Total	6472 / 100	288 / 100

Table 9. Densities of ground squirrel and badger holes in 2 hunting grounds and respective control quadrats of an unknown adult badger, summer 2009.

Hunting ground no.	*Number of Richardson's ground squirrel holes*		*Number of badger holes*	
	Hunting ground	*Control plots*	*Hunting ground*	*Control plots*
1	54	14	14	0
		26		0
2	42	21	9	4
		8		0

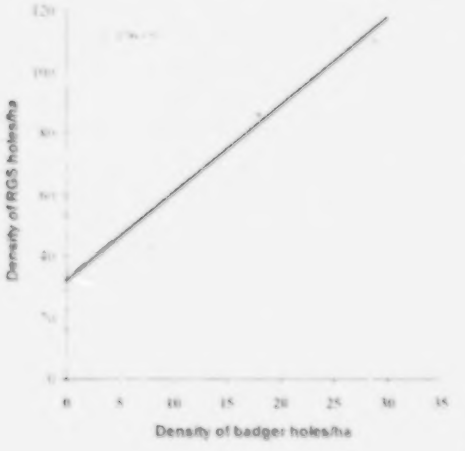

Figure 6. Relationship between the densities of badger and Richardson's ground squirrel holes/ha, summer 2009.

6.4.1.4 Scat analyses

2008

Richardson's ground squirrel remains decreased significantly ($P < 0.02$) in frequency from April-July to October-November. The August-September frequency of scats with ground squirrel remains was intermediary between spring-summer and fall (Table 10). The mean volume of Richardson's ground squirrel was significantly larger ($P < 0.05$) in June-July (85.7 ± 37.8%) than in October-November (16.9 ± 37.3%). Although volumes of ground squirrel remains differed markedly during other periods (Table 10), differences were not significant ($P > 0.05$). Ground squirrels remains were most important in June-July. In October- November, small mammals and insects were frequent prey items. Also, the prey diversity index was markedly higher in fall than earlier in the year (Table 10).

2009

Only a few scats were collected in 2009, and ground squirrel remains did not differ ($P > 0.05$) in frequency and volume from April-May to June-July (Table 11). The diversity of prey items was slightly higher in April-May than in June-July (Table 11).

2008 *vs.* 2009

Richardson's ground squirrel remains were similar ($P > 0.05$) in frequency in April-May of both years. However, the mean volume of ground squirrel remains in scats was significantly larger ($t = 11.533$, $P < 0.05$) in spring 2008 than in 2009. Ground squirrel remains were similar ($P > 0.05$) in frequency and volume in June-July of both years.

Table 10. Frequencies and mean volumes (%) of food items in badger scats, spring-fall 2008.

Food item	*April-May* n = 13*		*June-July* n = 7*		*August-September* n = 9*		*October-November* n = 12*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
MAMMALS								
Richardson's ground squirrel	11 (84.6)	84.6	6 (85.7)	85.7	4 (36.4)	50	3 (23.1)	16.9
Sagebrush vole (*Lemmiscus curtatus*)	0	0	0	0	0	0	2 (11.1)	4.6
Deer mouse	0	0	0	0	0	0	1 (5.6)	7.5
Western harvest mouse (*Reithrodontomys megalotis*)	0	0	0	0	0	0	1 (5.6)	6.2
Badger**	1 (-)	1.5	1 (-)	1.6	1 (-)	0.1	4 (-)	11.2
White-tailed deer (*Odocoileus virginianus*)	0	0	0	0	0	0	1 (5.6)	7.7 (27.7)
BIRDS								
Unidentified species	1 (7.7)	7.7	0	0	0	0	0	0
ARTHROPODS								
Insect	1 (7.7)	6.2	0	0	4 (36.4)	47.3	8 (44.4)	45.2
VEGETATION								
Grass-type	0	0	1 (14.3)	12.7	3 (27.3)	2.5	1 (5.6)	2
MISCELLANEOUS								
Unknown/ Pebbles	0	0	0	0		0	1 (5.6)	0.2
Prey Diversity Index	0.774		0.591		1.573		2.468	

* Some scats contained more than one food item. ** Scats with few contents; badger was not considered a prey item.

Table 11. Frequencies and mean volumes (%) of food items in badger scats, spring-summer 2009.

Food item	*April-May* n = 4*		*June-July* n = 5*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
Richardson's ground squirrel	3 (60.0)	50	4 (80.0)	80
Deer mouse	2 (40.0)	43.7	1 (20.0)	20
Badger**	1 (-)	6.3		
Prey Diversity Index	0.971		0.722	

* Some scats contained more than one food item. ** Badger was not considered a prey item.

6.4.2 *Long-tailed weasel*

6.4.2.1 Density of long-tailed weasels in study plots

Observations on the distribution of long-tailed weasels in study plots and their immediate surroundings suggest a density of ≥1 weasel/quarter section (64 ha) in summer (Table 12). On the basis of visual observations, study plots with more than one capture were likely inhabited by a family.

Table 12. Distribution and density of long-tailed weasels in Ponteix and Hazenmore study plots.

Time of Year	*Number of weasels*	*Size of the area*	*Vegetation*	*Location*
Summer	>3	Quarter section	Seeded grassland dominated by crested wheat grass.	O. Ballas
	1	Quarter Section	Seeded grassland dominated by crested wheat grass and alfalfa field.	O. Ballas C. Knox
	2	Quarter Section	Native grassland dominated by crested wheat grass and buckbrush, and annual crops.	N. MacKenzie

6.4.2.2 Scat analyses

2008

Latrines

In June 2008, Proulx et al. (2009b) found that the average number of juvenile ground squirrels (7 ± 2.2 juveniles; range of 4 to 9) captured in 4 study plots (nos. 10, 13, 15 and 16) with latrines was significantly lower ($P < 0.005$) than that of study plots (12.5 ± 3.3 juveniles; range of 10 to 20) without latrines. On the basis of the analysis of a limited number of scats collected at latrines, Proulx et al. (2009b) showed that ground squirrels were the main prey of weasels in these study plots. The following corresponds to the analysis of all scats that had been collected at these 4 latrines in 2008.

Richardson's ground squirrel remains were similar in frequency and volume in April-May and June-July 2008 in study plot no. 13 (Table 13). However, prey items were more diversified in summer (Table 13). There was no difference ($\chi^2 = 6.3$, df: 3, $P > 0.05$) in the frequency of ground squirrel remains in the summer scats of the latrines of study plots nos. 10, 13, 15 and 16. Mean volumes of ground squirrel remains in scats were similar ($F_{3,113} = 2.054$, $P > 0.05$) among study plots, and ranged from 71.9% to 94%. Other prey items were mainly small mammals and vegetation (Table 13).

Table 13. Frequencies and mean volumes (%) of food items in long-tailed weasel scats from 4 study plots with latrines, 2008.

Food item	*Study Plots*									
	No. 13				*No. 10*		*No. 15*		*No. 16*	
	April-May n = 21*		*June-July* n = 36*		*June-July* n = 16*		*June-July* n = 47*		*June-July* n = 16*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
MAMMALS										
Richardson's ground squirrel	15 (62.5)	65.5	34 (89.5)	87.5	12 (66.7)	71.9	44 (88.0)	94	15 (88.2)	89.1
Sagebrush vole	3 (12.5)	11.9	2 (5.3)	5.3	0	0	0	0	0	0
Deer mouse	3 (12.5)	10.7	1 (0.1)	2.0	0	0	1 (2.0)	2.1	0	0
Meadow vole (*Microtus pennsylvanicus*)	0	0	0	0	4 (22.2)	21.9	0	0	0	0
Western harvest mouse	0	0	1 (0.1)	2.6	0	0	0	0	1 (5.9)	6.2
ARTHROPODS										
Insect	0	0	0	0	0	0	1 (2.0)	0.1	0	0
VEGETATION										
Grass-type	3 (12.5)	11.9	1 (0.1)	2.6	2 (11.1)	6.2	4 (8.0)	3.8	1 (5.9)	4.7
Prey Diversity Index	1.549		0.398		1.224		0.680		0.642	

* Some scats contained more than one food item.

All scats

A total of 197 scats were collected from April to September 2008. The frequency of Richardson's ground squirrel remains in scats was similar ($P > 0.05$) in April-May and June-July, but was significantly lower ($P < 0.001$) in August-September (Table 14). The highest prey diversity index was in August-September; the lowest was in April-May (Table 14). The mean volume of Richardson's ground squirrel remains differed significantly ($F_{2,193} = 24.599$, $P < 0.005$) among periods. It was significantly larger ($P < 0.05$) in June-July (80.9 ± 38.6%) than in April-May (60.8 ± 46.0%) and August-September (23.1± 42.9%). The April-May mean volume was also significantly ($P < 0.05$) higher than in August-September. Other prey included small mammals, insects and vegetation (Table 14).

Table 14. Frequencies and mean volumes (%) of food items in long-tailed weasel scats, spring-summer 2008.

Food item	*April-May* n = 35*		*June-July* n = 135*		*August-September* n = 26*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
MAMMALS						
Richardson's ground squirrel	26 (59.1)	60.8	114 (79.7)	80.9	7 (25.0)	23.1
Sagebrush vole	5 (11.4)	11.4	6 (4.2)	4.4	9 (32.1)	34.6
Deer mouse	3 (6.8)	6.4	3 (2.1)	2.0	4 (14.3)	15.3
Meadow vole	1 (2.3)	2.9	4 (2.8)	3.0	0	0
Western harvest mouse	0	0	3 (2.1)	2.2	0	0
BIRDS						
Unidentified species	0	0	1 (0.7)	0.8	1 (3.6)	3.9
ARTHROPODS						
Insect	0	0	2 (1.4)	0.8	6 (21.4)	19.3
VEGETATION						
Grass-type	9 (20.5)	18.5	10 (7.0)	5.9	1 (3.6)	3.8
Prey Diversity Index	1.663		1.236		2.249	

* Some scats contained more than one food item.

2009

In April-May, all scats were found in the same portion of a Ponteix crested wheat field nearby a road with Rozol® bait stations. Only vegetation leftovers were found in the scats. In June-July, scats were collected in a Hazenmore pasture and in other crested wheat and alfalfa-crested wheat fields in Ponteix. Richardson's ground squirrel remains differed ($P > 0.05$) in frequency and volume between periods (Table 15). Prey index diversity was nil in spring, and 1.222 in June-July.

Table 15. Frequencies and mean volumes (%) of food items in long-tailed weasel scats, spring-summer 2009.

Food item	*April-May* n = 15*		*June-July* n = 18*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %)*
MAMMALS				
Richardson's ground squirrel	0 (0)	0	12 (63.2)	66.7
Deer mouse	0 (0)	0	4 (21.2)	22.2
West harvest Mouse	0 (0)	0	1 (5.3)	0.3
VEGETATION				
Grass-like	15 (100)	100	2 (10.5)	10.8
Prey Diversity Index	0		1.222	

* Some scats contained more than one food item.

2008 *vs.* 2009

There was a significant difference ($P < 0.005$) in the frequency of Richardson's ground squirrel remains in April-May of 2008 and 2009. In June-July, however, Richardson's ground squirrel remains were similar ($P > 0.05$) in frequency ($\chi^2 = 3.4$, df: 1, $P > 0.05$) and volume ($t = 1.420$, $P > 0.05$) during both years.

6.4.3 Coyote

6.4.3.1 Scat analyses

2008

Richardson's ground squirrel remains decreased in frequency from April-July to October-November (Table 16). There was no difference ($P > 0.05$) between the frequency of scats with ground squirrel remains in April-May and June-July. Richardson's ground squirrel remains were more often ($P < 0.02$) present in the June-July scats than in the August-September and October-November scats. Both April-May and October-November had a relatively high prey diversity index, and there was no difference ($P > 0.05$) between frequencies of scats with ground squirrel remains. The frequency of Richardson's ground squirrel remains was similar ($P > 0.05$) in August-September and October-November.

The mean volume of Richardson's ground squirrel remains decreased significantly ($F_{3,46} = 8.705$, $P < 0.05$) from spring to fall. The largest ground squirrel mean volume was in June-July, followed in order of decreasing importance by April-May ($P > 0.05$), October-November ($P < 0.05$), and August-September ($P < 0.05$). Mean volumes were similar ($P >$

0.05) in August-September and October-November.

Table 16. Frequencies and mean volumes (%) of food items in coyote scats, spring-fall 2008.

Food item	*April-May* n = 10*		*June-July* n = 6*		*August-September* n = 21*		*October-November* n = 13*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
MAMMALS								
Richardson's ground squirrel	4 (23.5)	40.0	4 (50.0)	55.0	0	0	1 (4.3)	3.9
Northern grasshopper mouse (*Onychomys leucogaster*)	0	0	1 (12.5)	0.8	0	0	3 (13.0)	1.5
Deer mouse	1 (5.9)	10.0	0	0	3 (10.7)	10.5	1 (4.3)	0.8
Norway rat	0	0	0	0	0	0	1 (4.3)	7.3
Western harvest mouse	3 (17.6)	20.3	0	0	0	0	0	0
Badger	1 (5.9)	10.0	2	25.0	0	0	4 (17.4)	8.4
White-tailed deer	0	0	0	0	0	0	1 (4.3)	6.9
Pronghorn (*Antilocarpa americana*)	0	0	0	0	0	0	1 (4.3)	3.8
Cattle (*Bos taurus*)	1 (5.9)	9.5	0	0	1 (3.6)	0.5	1 (4.3)	7.7
ARTHROPODS								
Insect	5 (29.4)	0.5	1 (12.5)	15.8	20 (71.4)	80.1	9 (39.1)	51.9
VEGETATION								
Grass-type	2 (11.8)	9.7	0	0	4 (14.3)	8.8	1 (4.3)	7.6
MISCELLANEOUS								
Pebbles**	0		0	0	1 (3.6)	0.1	1 (4.3)	0.2
Prey Diversity Index	2.538		1.750		1.266		2.717	

* Some scats contained more than one food item. ** Not considered a prey item.

2009

Only 6 scats were collected in April-May, and they did not contain remains of Richardson's ground squirrels (Table 17) Prey were diversified.

A total of 57 scats were collected at a coyote den in July 2009. Richardson's ground squirrel remains were dominant, followed in importance by small mammals (Table 17). Prey diversity index was estimated at 1.263.

Table 17. Frequencies and relative volumes (%) of food items in coyote scats, spring-summer 2009.

Food item	*April-May* n = 6*		*June-July* n = 57*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
Richardson's ground squirrel	0	0	43 (72.9)	74.0
Deer mouse	1 (14.3)	5.0	7 (11.9)	12.3
Western harvest mouse	1 (14.3)	11.7	5 (8.5)	8.8
Badger	1 (14.3)	16.6	0	0
White-tailed deer	1 (14.3)	16.6	0	0
Cattle	1 (14.3)	16.6	0	0
Insect	2 (28.6)	33.3	0	0
Vegetation			4 (6.8)	4.9
Prey Diversity Index	2.523		1.263	

* Some scats contained more than one food item.

2008 *vs.* 2009

There was no significant difference ($P > 0.005$) in the frequency and mean volume of Richardson's ground squirrel remains in April-May of 2008 and 2009.

6.4.4 Red fox

6.4.4.1 Scat analyses

In 2008 and 2009, investigations of red fox food habits focused on dens only. In 2008, despite extensive search, only 2 dens were found. In 2009, red foxes were more abundant, and 8 dens (1 in spring, 7 in summer) were found.

2008

Mankota den – Richardson's ground squirrel remains were similar ($P > 0.05$) in frequency and volume in spring and summer (Table 18). During both periods, ground squirrel remains represented ≥ 50% of prey items. The prey diversity index was 1.844 in April-May, and 1.906 in June-July.

Kincaid den – Only June-July scats were collected at this den. Food habits were diversified but ground squirrel remains were dominant (Table 18).

Mankota vs. Kincaid dens – There was no significant difference ($P > 0.005$) in frequency and mean volume of Richardson's ground squirrel remains in June-July scats of Mankota and Kincaid. Prey diversity index was slightly lower in Kincaid scats (Table 18).

Table 18. Frequencies and mean volumes (%) of food items in red fox scats, spring-summer 2008.

Food item	*Mankota Den*				*Kincaid Den*	
	*April-May** *n = 6*		*June-July** *n = 41*		*August-September** *n = 41*	
	Frequency (% of prey items)	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*	*Frequency (% of prey items)*	*Mean volume - %*
MAMMALS						
Richardson's ground squirrel	3 (42.9)	50	30 (63.8)	68.8	35 (71.4)	76.3
Red-backed vole (*Clethrionomys gapperi*)	0	0	1 (2.1)	2.4	0	0
Deer mouse	2 (28.6)	17.5	6 (12.8)	14.6	4 (8.2)	6.6
Western harvest mouse	1 (14.3)	16.7	2 (4.3)	2.9	3 (6.1)	5.0
Badger	0	0	1 (2.1)	1.2	0	0
Mule deer (*Odocoileus hemionus*)	0	0	1 (2.1)	2.4	0	0
BIRDS						
Unidentified species	0	0	2 (4.3)	0.7	2 (4.1)	4.9
ARTHROPODS						
Insects			3 (6.4)	5.6	2 (4.1)	4.6
VEGETATION						
Grass-type	0	0	1 (2.1)	1.2	3 (6.1)	2.7
Prey Diversity Index	1.844		1.906		1.513	

* Some scats contained more than one food item.

2009

Mankota den – Thirteen scats were found in April-May only; the den became inactive in June. Ground squirrel remains were present in only 5 (38.5%) of scats. Prey index diversity was 1.826 (Table 19).

All summer dens – Richardson's ground squirrel remains were similar ($P > 0.05$) in frequency and volume among all dens (Table 19). Ground squirrel remains represented > 60% of prey items. The prey diversity index ranged from 1.164 to 1.967 (Table 19).

Table 19. Frequencies and mean volumes (%) of food items in red fox scats in spring-summer 2009 dens.

Food item	Study Plots															
	Mankota April-May* n = 13		Kincaid June-July* n = 21		Hazenmore 1 June-July* n = 64		Hazenmore 2 June-July* n = 17		Hazenmore 3 June-July* n = 47		Hazenmore 4 June-July* n = 53		Ameroid June-July* n = 28		Ponteix June-July* n = 86	
	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volum e - %	Frequency (% of prey items)	Mean volume - %	Frequency (% of prey items)	Mean volume - %
MAMMALS																
Richardson's ground squirrel	5 (38.5)	38.5	13 (54.2)	61.0	50 (74.6)	78.1	14 (70.0)	82.2	36 (73.5)	76.6	37 (66.1)	69.8	17 (60.0)	60.7	60 (67.4)	69.4
Sagebrush vole	0	0	0	0	0	0	0	0	0	0	1 (1.8)	1.3	0	0		
Deer mouse	3 (23.1)	23.1	2 (8.3)	7.4	6 (9.0)	9.1	1 (5.0)	5.9	7 (14.3)	14.9	5 (8.9)	8.3	7 (24.1)	22.9	25 (28.1)	28.9
Meadow vole	0	0					0	0					0	0		
Western harvest mouse	4 (30.8)	30.8	1 (4.2)	4.8	4 (6.0)	6.3	2 (10.0)	9.4	2 (4.1)	4.3	2 (3.6)	3.8	2 (6.9)	7.2	1 (1.1)	1.2
White-tailed jackrabbit (*Lepus townsendii*)	0	0	0	0	0	0	0	0	0	0	1 (1.8)	1.9	0	0		
Deer (*Odocoileus* spp.)	0	0	4 (16.7)	19.0	1 (1.5)	1.6	0	0	0	0	0	0	0	0		
Pronghorn	0	0	1 (4.2)	4.8	0	0	0	0	0	0			0	0		
Cattle	0	0	0	0	0	0	0	0	0	0	1 (1.8)	1.9	0	0		
BIRDS																
Unidentified species	1 (7.7)	7.7	0	0	2 (3.0)	1.6	0	0	1 (2.0)	0.1	5 (8.9)	8.7	2 (6.9)	7.1		
ARTHROPODS																
Insect	0	0	0	0	1 (1.5)	1.6	2 (10.0)	0.2	0	0	2 (3.6)	3.8	0	0	2 (2.2)	0.2
VEGETATION																
Grass-type	0	0	3 (12.5)	3.1	3 (4.5	1.8	1 (5.4)	2.4	3 (6.1)	4.2	2 (3.6)	0.6	1 (3.0)	2.1	1 (1.1)	0.3
Prey Diversity Index	1.826		1.967		1.407		1.456		1.275		1.848		1.521		1.164	

* Some scats contained one than one food item

2008 vs. 2009

Richardson's ground squirrel remains were similar in frequency ($\chi^2 = 9.2$, df: 8, $P > 0.05$) and volume ($F_{8, 359} = 0.838$, $P > 0.05$) among all June-July dens of 2008 and 2009. The mean volumes of 2008 and 2009 June-July scats were 72.6% and 71.6%, respectively.

7.0 DISCUSSION

The 2009 field work confirmed our assessment of toxicants in 2007 and 2008. While many Rodenticides are available on the market, some of them have more potential than others when they are used under favorable environmental conditions and site preparation.

Phostoxin® – This toxicant certainly has the potential to efficiently control Richardson's ground squirrels, particularly in spring when soil moisture is higher. This is consistent with Salmon and Schmidt's (1984) recommendations. However, it is essential to flag the ground squirrel burrow holes in order to ensure total treatment. When treatment is conducted in fields where burrow holes have not been flagged, time is lost trying to find openings. When holes are missed, ground squirrels may receive a sub-lethal dose of gas and escape. We found that it is better to treat fields early in the morning, just before sunrise, when ground squirrels are still sleeping. In the evening, some animals are still up and may not be treated. During warm temperatures, it is easier to work in the morning with protective equipment. Nevertheless, applying Phostoxin® pellets is time-consuming, and one must limit the treatment to small areas (≤ 1 ha) where ground squirrel concentrations are higher.

Chlorophacinone – Past studies reported conflicting results about the ability of chlorophacinone to control ground squirrel populations (O'Brien 1979, Johnson-Nistler et al. 2005). In the last two years, we have demonstrated that this anticoagulant (Rozol® and Ground Force®) was very effective to control Richardson's ground squirrel populations. In grasslands, it consistently controlled > 70% of the animals, although it is better to use it in spring when there is less green vegetation. The 2008 study showed that the use of bait stations is less time-consuming than hole baiting, but it is more costly due to overfeeding of ground squirrels and non-target species. Hole baiting is very effective, and the 2009 spring tests showed that >70% control can be obtained at half concentrations. This is because one animal may use several holes. Hole baiting is creating small bait stations that animals visit and use over a 2-day period, before the second treatment. However, two problems are associated with chlorophacinone. First, this toxicant is not as effective when it is used in pure or mixed alfalfa fields. Plants rich in vitamin K (e.g., alfalfa) counteract the effect of anticoagulants on ground squirrels (Arjo and Nolte 2004). In 2009, chlorophacinone was more effective than usual in alfalfa because plants were dying due to drier conditions. On the other hand, on average, Ground Force® appeared to be more effective than Rozol® in alfalfa fields, possibly because winter rye is more attractive to ground squirrels than oats, and does not have enzymes that may interfere with the stability of chlorophacinone (Liphatech Inc.,

2008, personal communication). Concerns with the use of anticoagulants relate to primary poisoning of non-target species (e.g., small mammals and granivore birds) and secondary poisoning of predators (e.g., birds of prey and terrestrial carnivores) (Proulx and MacKenzie 2009). When anticoagulants are used over large areas, as is the case in southwest Saskatchewan, loss of predators may occur across landscapes and have a long-term impact on ground squirrel management. For this reason, it is more appropriate to use anticoagulants in sites with larger concentrations of ground squirrels in order to stop their expansion and invasion of surrounding fields. It is essential that moribund animals be removed; these animals usually appear on surface 3 days after first field application.

Strychnine – After 3 years of research in southwest Saskatchewan (Proulx and Walsh 2007, Proulx et al. 2009a, and this study), there is no doubt that RTU baits are ineffective to control ground squirrel populations. In contrast, FM strychnine-treated oats were found effective in 2008, when we used a freshly produced strychnine solution. In 2007, when the product was 5 years-old, the efficacy of FM strychnine dropped significantly and control levels were similar to those obtained with RTU baits. When the strychnine solution was 1 year-old, its control efficacy dropped slightly. Overall, FM strychnine meets the acceptation criteria of this research program. However, one must wonder about the unreliability of the product once it has been stored over winter. Is strychnine, or the anise oil attractant, lost over time? More research with freshly produced strychnine needs to be conducted in the future to ascertain its ability to control ≥70% of ground squirrel populations. Work conducted in 2008 (Proulx et al. 2009a) and this year showed that it is not advantageous to change bait. Hulless oats are as attractive to ground squirrels as canary seeds (Proulx et al. 2009a), and more attractive than alfalfa pellets (this study). However, compliance analyses should be conducted to ensure that strychnine solutions are appropriate. One major problem associated with strychnine is its impact on non-target species, and its secondary persistence (Proulx and MacKenzie 2009). In order to minimize non-target poisoning, and the loss of predators (particularly birds of prey), it is essential to develop a delivery system that confines poisoned animals to an area that is not accessible by other wildlife species. This study showed that the use of a multi-capture pen trap would help greatly in reducing non-target species poisoning. Because the ground squirrels die in the trap, predators and scavengers cannot access them and be poisoned. Of course, the true efficacy of the pen trap still needs to be assessed with freshly produced strychnine baits, and over large areas. The current use of strychnine is time-consuming and labor-intensive as it requires that bait be deposited in burrow holes and covered with dirt. Such a protocol is almost impossible to implement over large areas. There is a need to render baits more attractant to ground squirrels, particularly if they are used in pen traps. Freshly produced strychnine, and the use of attractants and additives to increase bait acceptability and consumption, should be considered for the long-term use of this toxicant.

When we initiated toxicant investigations in 2007, farmers and government agencies had many questions about the efficacy of various toxicants. Due to limited time and

resources, it was impossible to assess all toxicants over a short time period and in many sites. We decided to test poisons over time, using a few study plots every year, and under different environmental conditions. This was a successful approach as it allowed us to assess poisons under diverse temperatures and moisture regimes, in various crops, with different baits, and with different product generations. On an annual basis, because tests were conducted in a few study plots only, decisions to further investigate some poisons were based on limited statistical analyses and observations. However, after 3 years of research, complete datasets suggest that the right decisions were made year after year. This research program allowed us to assess limitations in the application of Phostoxin®, and advantages and risks associated with the use strychnine and anticoagulants. This research program also allowed us to develop an evaluation protocol based on capture-recapture of ground squirrels. The most difficult aspect of the research was to deal with natural predation during testing. In 2009 and 2010, high natural predation levels resulted from a concentration of predators in some study plots. For example, in 2009, one control study plot was inhabited by two badgers, one weasel family, nesting Swainson's hawks (*Buteo swainsoni*), and 1 red fox. In 2010, 8 ferruginous hawks (*Buteo regalis*), 1 badger, 2 cats and 1 dog were seen daily in one control study plot. Although natural predation levels varied from year to year, it had to be taken into consideration to properly assess the true efficacy of toxicants to control ground squirrel populations.

Phostoxin®, Rozol®, Ground Force®, and FM Nu-gro strychnine should be used judiciously in order to be effective, to minimize non-target hazards, and to be cost-effective (see Witmer et al. 2007). Ramsay and Wilson (2000) discussed ecologically-based baiting strategies for rodents in agricultural systems.

7.2 Ground squirrel-Vegetation Height Relationship

Although the number of burrow openings is not an absolute estimate of Richardson's ground squirrel densities, they are a reliable approximation of the size of populations, i.e., light or heavy infestations. Downey et al. (2006) found that ground squirrels selected against areas with tall grass (>30 cm). Our study showed that the presence of ground squirrels dropped significantly when vegetation reached a minimum height of only 15 cm. This is in agreement with Proulx and MacKenzie's (2009) findings. Richardson's ground squirrels prefer to establish their burrow systems in fields with shorter vegetation and good visibility (Yensen and Sherman 2003). At the management level, this suggests that, in drought-stricken zones such as the communities of southwest Saskatchewan (Liu et al. 2004, Barrow 2009), rotational grazing, the seeding of a mixture of improved species of grasses and legumes, and the maintenance of dense grass cover (Heath et al. 1973) will reduce ground squirrel colonization and produce high quality forage that is more resistant to drier environmental conditions.

7.3 Assessment & Development of Capture-efficient Trapping devices

Concerns about the welfare of trapped animals is a major concern for the public, environmental groups, and scientists (Schmidt and Bruner 1981, Proulx and Barrett 1989, Iossa et al. 2007). As there are few killing traps for ground squirrels available on the market,

the assessment of the ability of the GT2006 traps was essential. This trap is humane and can quickly render unconscious Richardson's ground squirrels struck in the head region. One must be patient when using it. Ground squirrels that sought refuge in their burrow system do not always come back immediately, and they do not always use the same opening to exit their burrow system. It is therefore necessary to use several traps at the same time to capture one individual. At landscape level, the use of the GT206 would require hundred of traps and the operation would be time-consuming and labor-intensive. We recommend that this trapping device be used for the control of ground squirrels in areas where chemical control is not a solution, and for small population concentrations.

Compared to the GT2006, the multi-capture pen trap is not labor-intensive. The trap remains functional capture after capture. When captive ground squirrels feed on strychnine bait, they die within the trap and have no impact on other wildlife. Tests with the pen trap and strychnine showed that control levels were similar to those obtained with strychnine placed in burrow openings. It is, however, less time-consuming. The development of the pen trap was not simple. It took into consideration the behavior of ground squirrels approaching foreign objects, and their ability to escape. An industrial version of the prototype trap should be produced and its capture efficiency should be evaluated with different attractants. The pen trap should also be tested with freshly produced strychnine baits to assess its ability to attract, capture and dispatch ground squirrels. Finally, it is important to determine how far apart traps should be set, and how often they should be moved, to effectively control ground squirrel populations over large areas.

7.3 Predation

The 2009 research program demonstrated once more that chemical control of ground squirrel populations may impact on the sustainability of predator communities. Where predators are abundant, and particularly where they have coevolved with the prey species, density-dependent or delayed density-dependent predation may impact on large fluctuations of rodent population densities (Witmer and Proulx 2010). Ferruginous hawks are specialist predators feeding almost exclusively on Richardson's ground squirrels (Lokemoen and Duebbert 1976, Schmutz et al. 1980). Birds of prey may succumb to strychnine and anticoagulant poisoning (Proulx and MacKenzie 2009, Proulx et al. 2009a, and this study). This is also true for badgers, long-tailed weasels, and foxes (Proulx and MacKenzie 2009). Also, a decrease in predator populations certainly contributed to the expansion of ground squirrel populations during 2000-2009 in southwest Saskatchewan. Chemical control must therefore be judiciously used across landscapes.

This study showed that badger, long-tailed weasel, and red fox food habits consisted mainly of ground squirrels in spring and summer. Scat analyses showed that ground squirrels were an important prey in June-July. However, all predators changed their diet starting in August, when ground squirrels retired for the winter. Small mammals and insects then became more important. It is interesting to note that vegetation was a constant component of long-tailed weasel diets. In 2009, however, weasel scats contained vegetation only, a finding that we cannot explain. Coyotes did not appear to be as effective as the other terrestrial

predators, but they may still have an impact on ground squirrel populations when they have their pups.

Our findings suggest that depredation of ground squirrels by red foxes may have been underestimated by wildlife managers. Red fox feeding habits vary markedly with annual and seasonal availability of food items. While reviews of diets usually list small mammals and insects as important food items, ground squirrels are not listed as main prey (Samuel and Nelson 1982, Cypher 2003). The red fox-ground squirrel relationship warrants further investigations. It is known that some red fox dens may be used over multiple generations (Stanley 1963) and may be enlarged each year (Pils and Martin 1978). Also, movement patterns within home ranges are strongly influenced by the distribution of food resources (Ables 1975). If red foxes become specialist predators of ground squirrels when they have their pups, then they could play an important role in the control of this species along field edges and fences. It appears that fox population densities were much higher in 2009 than in previous research years. This may be a delayed ground squirrel density-dependent population irruption, or the result of an apparent decrease in coyote numbers (Sargeant et al. 1987) due to control by local farmers.

Our findings on multi-scale habitat selection by badgers confirmed Proulx et al.'s (2009b) findings that badgers do not establish their home range and hunting grounds at random. Their distribution across landscapes indicates that they associate with larger concentrations of Richardson's ground squirrels, and therefore aim to maximize their foraging activities. Multi-scale habitat selection was also found with other mustelids (Lofroth 1993, Weir and Harestad 2003). On the basis of this finding, we suggest that multi-scale habitat selection by badgers be further investigated with more animals in different environments.

While estimated badger and weasel densities were similar in 2009 and 2010, more data on their distribution and numbers should be collected in landscapes where ground squirrels are not poisoned. Such information would be useful in the development of an Integrated Pest Management Program (Witmer and Proulx 2010).

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9.0 LITERATURE CITED

Ables, E. D. 1975. Ecology of the red fox in America. Pages 216-236 *in* M. W. Fox, editor, The wild canids. Van Nostrand Reinhold, New York, USA.

Adorjan, A. S., and G. B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Ontario Department of Lands and Forest Research Report (Wildlife) 90. 64 pages.

Arjo, W. M., and D. L. Nolte. 2004. Assessing the efficacy of registered underground baiting products for mountain beaver (*Aplodontia rufa*) control. Crop Protection 23: 425-430.

Barrow, E. 2009. Climate scenarios for Saskatchewan. Prairie Adaptation Research Collaborative report, Regina, Saskatchewan. 131 pages.

Chandler, A. C. 1916. A study of the structure of feathers with reference to their taxonomic significance. Zoology (California) 13: 243-266.

Cypher, B. L. 2003. Foxes. *Vulpes* species, *Urocyon* species, and *Alopex lagopus*. Pages 511-546 *in* G. A. Feldhamer, B. C. Tompon,a nd J. A. Chapman, editors. Wild mammals of North America. Biology , management, and conservation. 2nd edition. The Johns Hopkins University Press, Baltmore, Maryland, USA.

Downey, B. A., P. F. Jones, R. W. Quinlan, and G. J. Scrimgeour. 2006. Use of playback alarm calls to detect and quantify habitat use by Richardson's ground squirrels. Wildlife Society Bulletin 34: 480-484.

Heath, M. E., D. S. Metcalfe, and R. F. Barnes. 1973. Forages. The science of grassland agriculture. Iowa State University Press, Ames, Iowa.

Henderson, C. F., and E. W. Tilton. 195. Tests with acaricides against the brown wheat mite. Journal of Economic Entomology 48: 157-161.

Iossa, G., C. D. Soulsbutry, and S. Harris. 2007. Mamal trapping: a review of animal welfare standards of killing and restrainingtraps. Animal Welfare 16: 1-18.

Johnson-Nistler, C. M., J. E. Knight, and S. D. Cash. 2005. Considerations related to Richardson's ground squirrel (*Spermophilus richardsonii*) control in Montana. Agronomy Journal 97: 1460-1464.

Krebs, C. 1978. Ecology: the experimental analysis of distribution and abundance. Second edition. Harper & Row Publ., New York.

Liu, J., R. E. Stewart, and K. Szeto. 2004. Moisture transport and other hydrometeorological features associated with the severe 2000/01 drought over the Western and Central Canadian Prairies. American Meteorological Society 17: 305-319.

Lofroth, E. C. 1993. Scale dependent anlyses of habitat selection by marten in the sub-boreal spruce biogeoclimatic zone, British Columbia. M.Sc. Thesis, Simon Fraser University, Burnaby, British Columbia.

Lokemoen JT, Duebbert HF. 1976. Ferruginous hawk nesting ecology and raptor populations in northern South Dakota. The Condor 78: 464-470

Marsh, R. E., R. H. Schmidt, and W. Howard. 1987. Secondary hazards to coyotes of ground squirrels poisoned with 1080 or strychnine. Wildlife Society Bulletin 15: 380-385.

Matschke, G. H, and K. A. Fagerstone. 1984. Efficacy of two-ingredient fumigant on

Richardson's ground squirrels. Proceedings Vertebrate Pest Conference 11: 17-19.
Moore, T. D., L. E. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Department Bulletin No. 14. 117 pages.
O'Brien, J. 1979. Field trials of Maki and Rozol for control of Richardson's ground squirrel. Nevada State Department of Agriculture, Reno, Nevada, Mimeograph. 3 pages.
Pils, C. M., and M. A. Martin. 1978. Population dynamics, oredator-prey relationships and management of the red fox in Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 105,.
Powell, R. A., and G. Proulx. 2003. Trapping and marking terrestrial mammals for research: integrating ethics, standards, techniques, and common sense. Institute of Laboratory Animal Research Journal 44: 259-276.
Proulx, G. 1998. Evaluation of strychnine and zinc phosphide baits to control northern pocket gopher populations in alfalfa fields, in Alberta, Canada. Crop Protection 17: 135-138.
Proulx, G. 2002. Effectiveness of trapping to control northern pocket gophers in agricultural lands in Canada. Proceedings Vertebrate Pest Conference 20: 26-31.
Proulx, G. 2006. Using forest inventory data to predict winter habitat use by fisher *Martes pennanti* in British Columbia, Canada. Acta Theriologica 51: 275-282.
Proulx, G. 2009. Conserving American Marten *Martes americana* winter habitat in sub-boreal spruce forests affected by Mountain Pine Beetle *Dendroctonus ponderosae* infestations and logging in British Columbia, Canada. Small Carnivore Conservation 41: 51-57.
Proulx, G., and M. W. Barrett. 1989. Animal welfare concerns and wildlife trapping: ethics, standards and commitments. Transactions of the Western Section of the Wildlife Society 25: 1-6.
Proulx, G., M. W. Barrett, and S. R. Cook. 1989. The C120 Magnum: an effective quick-kill trap for marten. Wildlife Society Bulletin 17: 294-298.
Proulx, G., A. J. Kolenosky, and P. J. Cole. 1993. Assessment of the Kania® trap to humanely kill red squirrels (*Tamiasciurus hudsonicus*) in enclosures. Journal of Wildlife Diseases 29: 324-329.
Proulx, G., and K. MacKenzie. 2009. Review of control methods and severity of the Richardson's ground squirrel problem in Saskatchewan. Alpha Wildlife Research & Management Ltd. report submitted to Saskatchewan Agriculture Development Fund, Regina, Saskatchewan. 45 pages.
Proulx, G., N. MacKenzie, B. Proulx, K. MacKenzie, and K. Walsh. 2009b. Relationships among predators, prey and habitat use in southern Saskatchewan, 2008. Alpha Wildlife Research & Management Ltd. report submitted to Saskatchewan Agriculture Development Fund, Regina, Saskatchewan. 28 pages.
Proulx, G., J. A. McDonnell, and F. F. Gilbert. 1987. Effect of water level fluctuations on muskrat, *Ondatra zibethicus*, predation by mink, *Mustela vison*. Canadian Field-Naturalist 101: 89-92.
Proulx, G., and E. C. O'Doherty. 2006. Snowtracking to determine *Martes* winter

distribution and habitat use. Pages 211-224 *in* M. Santos-Reis, J.D.S. Birks, E.C. O'Doherty, and G. Proulx, editors. *Martes* in carnivore communities. Alpha Wildlife Publications, Sherwood Park, Alberta, Canada.

Proulx, G., and K. Walsh. 2007. Effectiveness of aluminium phosphide, strychnine, and chlorophacinone to control Richardson's ground squirrels (*Spermophilus richardsonii*) in spring, in southern Saskatchewan. Alpha Wildlife Research & Management Ltd. report submitted to Pest Management Regulatory Agency, Ottawa, Ontario. 36 pages.

Proulx, G., K. Walsh, N. MacKenzie, and K. MacKenzie. 2009a. Assessment of the effectiveness of Rozol®, Phostoxin®, Strychnine, RoCon®, and various treatments to control Richardson's ground squirrels (*Spermophilus richardsonii*) in southern Saskatchewan, in spring and summer 2008. Alpha Wildlife Research & Management Ltd. report submitted to Saskatchewan Agriculture Development Fund, Regina, Saskatchewan. 46 pages.

Ramey, C. A., G. H. Matschke, P. L. Hegdal, G. R. McCann, and R. M. Engeman. 2002. Safe efficacy of three strychnine alkaloid bait concentrations for hand-baiting control of plains pocket gophers. International Biodeterioration and Biodegredation 49: 139-143.

Ramsey, D., and J. Wilson. 2000. Towards ecologically-based baiting strategies for rodents in agricultural systems. International Biodeterioration and Biodegradation 45: 183-197.

Salmon, T. P., and R. H. Schmidt. 1984. An introductory overview to California ground squirrel control. Proceedings Vertebrate Pest Conference 11: 32-37.

Samuel, D. E., and D. B. Nelson. 1982. Foxes. *Vulpes vulpes* and allies. Pages 475-490 *in* J. A. Chapman and G. A. Feldhamer,e ditors, Wild mammals of North America. The Johns Hopkins University Oress, Baltimore, Maryland, USA.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51: 285-293.

Saskatchewan Agriculture and Food. 2001. Final report - 2001 Saskatchewan "Gopher" survey. Saskatchewan Agriculture and Food, Regina, Saskatchewan, 16 pages.

Schmidt, R. H., and J. G. Bruner. 1981. A professional attitude toward humaneness. Wildlife Society Bulletin 9: 289-291.

Schmutz JK, Schmutz SM, Boag DA. 1980. Coexistence of three species of hawks (*Buteo* spp.) in the prairie-parkland ecotone. Canadian Journal of Zoology 58: 1075-1089.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill, New York.

Sokal, R. R., Rohlf F. J. (1981) Biometry. 2nd edition. W. H. Freeman and Co., San Francisco, California, USA.

Stanley, W. C. 1963. Habits of the red fox in northeastern Kansas. University of Kansas Museum of Natural History Miscellaneous Publications 34: 1-31.

Weir, R. D., and A. S. harestad. 2003. Scale-dependent habitat selectivity by fishers in south-central British Columbia. Journal of Wildlife Management 67: 73-82.

Witmer, G. W., G. H. Matschke, and D. L. Campbell. 1995. Field trials of pocket gopher with cholecalciferol. Crop Protection 14: 307-309.

Witmer, G., and G. Proulx. 2010. Rodent outbreaks in North America. *In* G. Singleton, S.

Belmain, P. Brown, and B. Hardy, editors, Rodent outbreaks – ecology and impacts. International Rice Research Institute, Metro Manila, Philippines.
Witmer, G, R. Sayler, D. Huggins, and J. Capelli. 2007. Ecology and management of rodents in no-till agriculture in Washinton, USA. Integrative Zoology 2: 154-164.
Wood, D. A., and J. Phillpson. 1977. The utilization of poison hoppers designed for grey squirrel (*Sciurus carolinensis*) control. Biological Conservation 11: 119-127.
Yensen, E., and P. W. Sherman. 2003. Ground squirrels. *Spermophilus* and *Ammospermophilus* species. Pages 211-231 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors, Wild mammals of North America. Biology, management, and conservation. The John Hopkins University Press, Baltimore, Maryland, USA.
Zar, J. H. (1999) Biostatistical analysis. 4th edition, Prentice Hall, New Jersey, USA.